Lesson Plan: Evidence of Common Ancestry

Note to teachers: This lesson is intended to introduce evidence of common ancestry to students in an engaging way, without beating them over the head and trying to convince them that evolution is real. Instead, we ask students to identify bones while noticing details and wondering about the implications. Our hope is that students will become curious, ask questions, bring background knowledge to bear, and make hypotheses in a similar way to what Darwin and others must have done when they noticed similarities between bone structures.

The following excerpt from **A Framework For K-12 Science Education** considers the question: *"What evidence shows that different species are related?*

"Biological evolution, the process by which all living things have evolved over many generations from shared ancestors, explains both the unity and the diversity of species. The unity is illustrated by the similarities found between species; which can be explained by the inheritance of similar characteristics from related ancestors...

"Evidence for common ancestry can be found in the fossil record, from comparative anatomy and embryology, from the similarities of cellular processes and structures, and from comparisons of DNA sequences between species. The understanding of evolutionary relationships has recently been greatly accelerated by using new molecular tools to study developmental biology, with researchers dissecting the genetic basis for some of the changes seen in the fossil record, as well as those that can be inferred to link living species (e.g., the armadillo) to their ancestors (e.g., glyptodonts, a kind of extinct gigantic armadillo)."

Note: The goal of this lesson is to prepare students to consider the possibility of common ancestry of all living things, understand homology, and understand the whale evolution reading.

Learning Objectives

- After viewing images of bones of several different species, extinct and living, and discussing the similarities, students will demonstrate understanding by writing a paragraph describing the evidence of common ancestry.
- Understand comparative anatomy as science in Darwin's day (classification of the natural world in order to understand its structure, Paley quote about seeing God in the world)
- Comparative anatomy: See similarities in skeletons between different contemporary animals.
- Fossil: See similarities in skeletons between different evolved forms (whales).

Materials

- Vocabulary sheet of evolution terms
- Evidence in Bones Slide Show
- Bones of the arm handout (comparing human and whale)
- How Whales Learned How To Swim (reading)
- Video about whale evolution: http://statedclearly.com/videos/what-is-the-evidence-for-evolution/section/transcript/
- Whale evolution charts

- 5 animal bones handout (with different “arm” bones)

Steps

Warm up (30 mins)

- Independent writing prompt: "What do you remember about Darwin's voyage around the world? Try to remember at least three things. Write in complete sentences."
- Students write independently; then pair share; then full group share out; teacher takes notes on the board.

Vocabulary Exercise (45 min)

- In this individual activity, students should place a checkmark under the column that describes their experience with the word:

I know the word and use the word	I know the word but don’t use it	I have heard the word, but I’m not sure what it means	I have never heard the word

- In the last column of the chart, students should write their best guess at the meaning of the word or use the word in a sentence.
- It may be helpful to model the first word, *anatomy*, from your experience. Reproduce the table on the board, check off the appropriate box and write a definition from your memory or use the word in a sentence. This should not be a dictionary definition of the word. We just want to know how familiar students are with these words already.
- Hand out chart and let students work independently.
- After students have worked through the word alone, you may want them to pair up and share their experience with the words and read each other’s definitions and sentences. You might then ask for volunteers to share with the class or just collect the charts to read before the next class.
- You might share the following word list with students as a support during the lesson.

Words from this lesson:

- anatomy - bodily structure of humans, animals, and other living organisms
- ancestor - someone you descended from
- evidence - a possible explanation using limited evidence as a starting point for further investigation
- extinct - died out, no longer living
- fossil - the remains of a prehistoric organism preserved in rock
- hypothesis - an informed guess based on evidence
- observe - to look closely
- organism - a living thing; an animal, plant or other life form
- origin - a point or place where something began
- species - a group of organisms that are able to interbreed and produce offspring
- theory - an explanation of all the known facts and observations
- homologous structures - a physical similarity that shows that two organisms are related through a common ancestor

Identify Bones Activity (50 min)

Materials: Evidence in Bones Slide Show (ppt)
Prep: Load Evidence in Bones Slide Show (ppt) so that it's ready for the following conversation. Load whale song and check speakers.

Put the following headings on the board or easel paper:

- What do you notice?
- What do you wonder?
- What are these bones?

  Create a graphic organizer with these headings in your notes. Write your observations, questions and hypotheses during our conversation.

Observation and Questioning activity - Identify whale flipper

- Say, "I need you to help me identify some bones."

Note: Keep it a secret! Don't give students any clues when they make guesses. All suggestions are good and interesting at this point. Alien? Maybe. Human? Interesting, what do you see that you makes you say that. Do what you can to build and maintain suspense. This means you should not give them clues about correct or incorrect guesses, since that will shut down people who might have made a wild guess. Also, guessing the animal isn't the point at the beginning, though it's entertaining. The standard response to guesses can be, "Hmm. What do you SEE that makes you say that?" then focus on close observation for the rest of the discussion.

- (Slide 1) Show first image of what looks like the bones of a hand. Don't give any clues yet about what it might be. Use the Notice and Wonder instructional routine to draw out student thinking.

Notice and Wonder Instructional Routine

- *Hand out or project the image.*
- *Give students some time to look at it own their own before talking with others.*
- *If there is time, ask students to talk in pairs about what they notice (what stands out to them) and what they wonder (what questions they have)?*
- *Bring students together for a large group conversation.*

*Ask students, "**What do you notice?**"*

Pause to let as many students as possible raise their hands. Call on students and record their noticings at the front of the room.

As you record students' thoughts, thank or acknowledge each student equally. Record all student suggestions. Avoid praising, restating, clarifying, or asking questions.

*Ask students, "**What are you wondering?**"*

Pause to let as many students as possible raise their hands. Call on students and record their wonderings at the front of the room.

Ask students, "Is there anything up here that you are wondering about? Anything you need clarified?" If you or the students have questions about any items, ask the students who shared them to clarify them further.

This procedure is adapted from the Math Forum (http://bit.ly/NotWonIntro).

- Following the routine above, take notes on what students notice, then take notes on their questions. Then ask them if they have any ideas about what these bones are. Take notes on their guess without giving them an indication if they are right or wrong. You might ask them to explain how they came to that guess.
- When students share things they noticed, they might say things like, "This is from a dinosaur," or "The bones are really old." In response, you might ask, "What do you see that makes you say that?" in order to draw out the visual details that students are using to make inferences. Add these details to chart paper along with other noticings.
- Ask for volunteers to share observations and questions. Take notes on easel paper or the blackboard under the Evidence, Questions and Hypotheses headings.
- At this point, you should have notes in three sections: What do you notice?, What do you wonder? and What are these bones? You will have notes on students' ideas for each section. Before moving on the next slide, Add Observations/Evidence, Questions and Hypotheses above each chart paper. This is what scientists do. They make careful observations, ask questions about what they see and then start to make hypotheses to explain what they see.

Observations/Evidence *(What do you notice?)*	*Questions* *(What do you wonder?)*	*Hypotheses* *(What are these bones?)*
It looks like a hand, but it's stretched out *There are too many joints.* *The bones are yellow, like they're old.* *There is a tag.* *...*	*Is it a foot or a hand?* *Is this animal still living or is it extinct?* *Is it in a museum?* *What does the tag say?* *...*	*It's from a dinosaur.* *Maybe a caveman.* *They're from an alien.* *...*

Questions for students as they share observations, questions and hypotheses:

- What do you see that makes you say that?
- What information could I give you that would be helpful to identify these bones?
- Is there something you sure this is not? What are some examples of things this is not?

- Hint (hit right arrow to display next image): Show image of man standing next to bones on wall. Qs: What do you notice? What new evidence do we have? What do you see that makes you say that?
- Hint: Show image of skeleton with rib cage. Ask students to add more details to the three charts.
- Hint: Show image of full skeleton.
- Hint: Play whale song.
- Show drawing of the whale, including skeleton. What do you notice about this image? What questions do you have? Add these notes to the charts.

Quickwrite

- Pull out your notebook and write about the activity we just finished. What surprised you? What did you learn? What new questions do you have?
- Ask students to share writing with a partner, then ask for volunteers to share out.

Identify "Arm" Bones (20 min)

- What is the takeaway from the last activity?
  Whale flipper bones and human hand bones are very similar.
- Display the arm bones from different species slide and/or give out handout
- Students work on **5 animal bones handout** individually. Write down your best guess for each animal. Share with a partner. Eventually, reveal the names of the animals.
- Show students a diagram of a human arm with the bones (humerus, ulna, radius, etc.) labelled. What do they notice? If given a few minutes, they should see that whales, humans, bats, lizards and birds have similar bones, though may look very different.
- (On the back of the worksheet) What other animals do you think have a similar bone structure in their forelimbs? Write down as MANY as you can. Brainstorm animals on the board.
- So, what do you think about the fact that cats and monkeys and bears all have a similar bone structure?

- Share this information:

  Darwin thought about this a lot. In The Origin of Species, he wrote: "*What can be more curious, than that the hand of a man, formed for grasping, that of a mole for digging, the leg of the horse, the paddle of the porpoise, and the wing of the bat, should all be constructed on the same pattern, and should include similar bones, in the same relative positions?*"

- Introduce the phrase *homologous structures*.

- Tell the class that these different arms are all examples of homologous structures.

  Human hands, whale flippers, bat wings and lizard feet are examples of homologous structures.

  What do you think *homologous* mean?

  Homologous structures may not perform the same function but they share common ancestry. For instance, the forelimbs of humans and bats are homologous structures. Although they are used differently, the basic skeletal structure is the same and they come from the same embryonic origin. Their similarity could mean they evolved from a common ancestor.

  Defining homology:
  http://evolution.berkeley.edu/evolibrary/article/similarity_hs_01

- Ask students how homologous structures (specifically the arms) could possibly lead to the idea of evolution from a common ancestor.

Whale Evolution (40 min)

Note: My students had a lot of concrete and specific questions about whales and whale evolution and how long whales have been around.

- I used the article "How Whales Learned to Swim" as a follow-up for my class. I adapted it to make it easier for students and came up with a few questions for it. - Meghan McNamara (Borough of Manhattan Community College)

- You can follow up on the whale evolution article with a video about the evidence for common ancestry, using the whale as an example (Stated Clearly video). Hand out video question guide and read over so students know what to listen for.

- Watch Stated Clearly video, up until 7:13 (before DNA, possibly). Students might ask to watch the video again. If so, tell them to write down what they remember first, then watch again to see what other information they catch.
- Students share responses with their table. Add information from each other's notes.
- Share responses from the full group, taking notes on the board.
- At the end, you might also ask: "Why might a land creature go into the sea?" (More food, escape predators)

Additional resource/optional activity: Whale evolution charts

- Look at whale evolution charts
    - What do you notice? What do you wonder?
    - Write practice test questions
        - *The high school equivalency test is written by a team of people who look at content from high school and figure out ways to find out if HSE students understand the material. If you can get in the mind of the test writer, you can definitely conquer the test. Imagine yourself as a test writer and write a practice question based on what we did today.*
        - What questions could be asked about these charts on the TASC test? Work with a partner to write a TASC question based on the chart. Write multiple choice answers for your practice question. Trade questions with another group.

Writing (10 min)

Darwin and other people in his time noticed similarities among different animals. In your journal entry, include details he might have noticed when he look at animal skeletons. Also include questions he might have asked himself as he thought at these animals.

Also include questions you have based on what we have done in the last three lessons.

Homefun

- Reading: Read chapters 1-3 in Krull.

Optional Follow-up Activities

Archeopteryx, Dromaeosaurus and Columba

- Small groups look at the skeletal images.
  What do you notice? What similarities do you see between the three skeletons? What differences? What do you think ischium means? Pubis? What questions do you have?
- Hand out images of the same animals with skin. Ask the groups to match up the images. *What do you notice?*
- Students try Regents practice test question. Give a few minutes independently. Discuss with a partner.

Whose shoulders did Darwin stand on?

People often think that Darwin came up with his theory on his own, but he actually used many other people's ideas. That is what science is. No one can make advances completely on their own. They base their ideas on other people's work and then take things a little further. I'm curious to know about the people who influenced Darwin.

- Reread independently some of the introduction to Charles Darwin, by Kathleen Krull. Highlight or underline a couple sections that are interesting. What stands out to you?
- Model note-taking by reading aloud some thoughts on the quotation from Isaac Newton, "If I have seen further [than other people] it is by standing upon the shoulders of giants." - Isaac Newton, 1675
- Model the response by writing/reading something like this: "I'm interested in this phrase and how it applies to Darwin. Many What's interesting to you about this quotation?
- Volunteers share what they wrote.

Complete the table based on your knowledge of the words in the left column. Read each word and then choose one of the four categories and mark your answer with a ✔ (checkmark). Then write your best guess at the meaning of the word in the right column. If it's easier, you can also just use the word in a sentence.

Word	I know the word and use the word	I know the word but don't use it	I have heard the word, but I'm not sure what it means	I have never heard the word	My best guess at the meaning of the word (or use the word in a sentence)
anatomy					
ancestor					
evidence					
extinct					
fossil					
hypothesis					
observe					
species					


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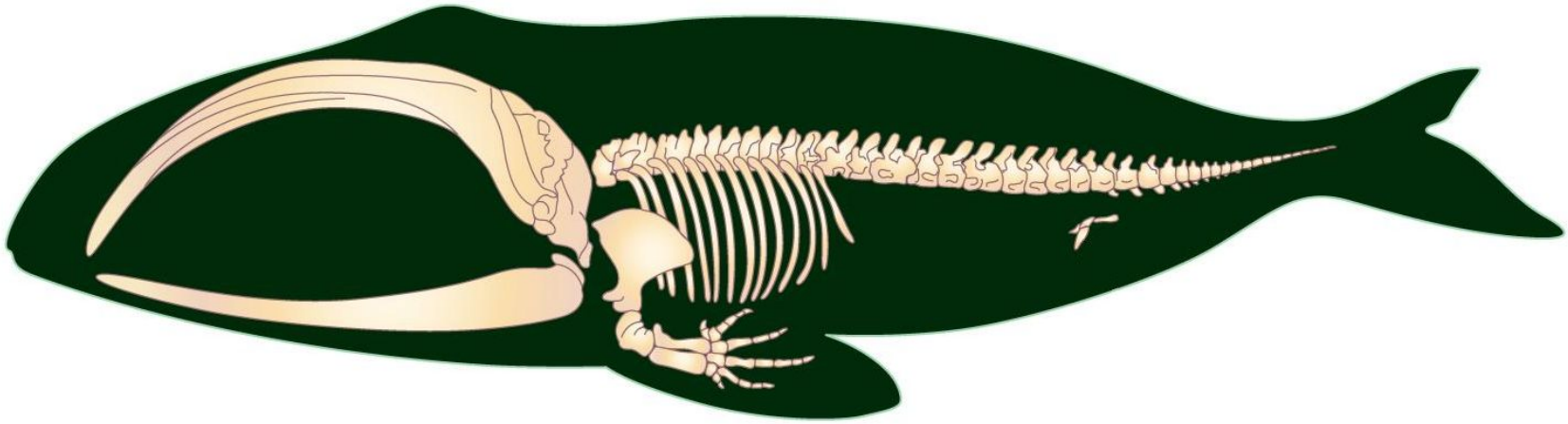
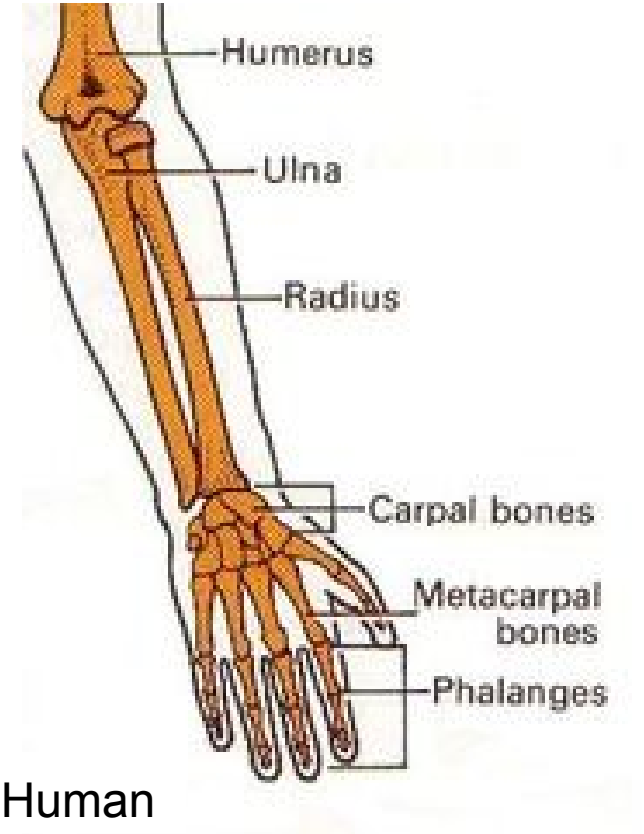


Can you identify what animal each of these bones are from?

What other animals do you think have a similar bone structure in their forelimbs? Write down as MANY different kinds of animals as you can.

Bones of the Arm

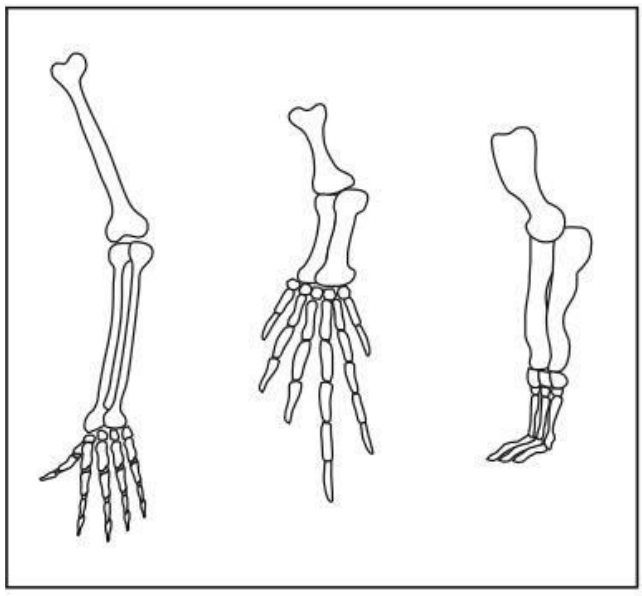


Human

Whale

Name: _____ Date: _____

The diagram below represents the bone arrangements in the front limbs of three different species of mammals – a human, a whale and a dog.



1. Which of these statements about the evolutionary history of humans, whales and dogs is supported by this diagram?
   A. Humans and whales share a common ancestor with each other, but not with dogs.
   B. Humans, whales and dogs share a common ancestor.
   C. Humans and whales do not share a common ancestor with each other or with dogs.
   D. Whales and dogs share a common ancestor, but whales and humans do not.

2. Use the diagram to explain *homologous structures*.

How Whales Learned to Swim

The mighty blue whale owes its swimming ability to a change in its anatomy that happened by chance. Fossils show early whales became good swimmers in a short blink of evolution – in about 10 million years.

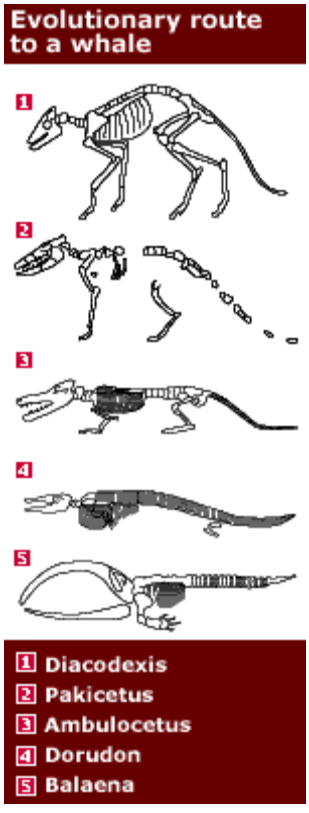
The earliest whales were wolf-sized land mammals

Scientists believe the ancestors of whales were land animals that crawled into the sea to escape predators or seek food. The mammals gradually lost their limbs and became fully adapted to living in the ocean.

According to new evidence, one of the secrets to adapting to an ocean environment was a smaller inner ear. The semi-circular inner ear system gives land mammals, including humans, a sense of balance. We only become aware of its role when something goes awry - such as feeling drunk, sea sick or riding a rollercoaster.

Animal acrobats

Modern whales, dolphins and porpoises (which are all members of a group called cetaceans) have similar inner ears to land mammals. But, in whales, dolphins and porpoises, the inner ear is smaller. Our inner ears, for example, are bigger for our size than those of the blue whale. However, unlike say a large elephant, a whale can make acrobatic leaps and turns without experiencing dizziness. This is thought to be because its smaller inner ear is less sensitive.



Fossils show that the inner ear of early whales evolved rapidly after they entered the sea. The adaptation enabled early whales to swim without becoming dizzy.

Marine diversity

Early whales probably became fully water-based about 5-10 million years after they took to the sea about 50 million years ago. It may sound like a long time but it is remarkably fast in evolutionary terms.

The mighty *Basilosaurus*, a carnivorous early whale

Scientists Rich Lane says that it is this trait, of small inner ears that did not make whales dizzy when they swam, that opened up a whole new environment for mammals to live in—the sea! Before this, mammals only lived on land.

In short, it explains how whales came to rule the oceans.

Questions about "How Whales Learned to Swim"

1) Who do scientists think were the ancestors of whales? How did their bodies adapt to their new environment?

2) What happened to the early whale's inner ear when it entered the sea? Why was this beneficial to early whales?

3) How long ago did whales become creatures that lived in the sea?

4) Evidence that supports the history of whale evolution was most likely obtained from the

   A. investigation of environmental niches

   B. study of fossil records

   C. comparison of the number of cells in organisms

   D. analysis of food chains and food webs

5) The fossil record of ancient life forms provides scientific evidence of

   A. direct harvesting

   B. selective breeding

   C. gene manipulation

   D. evolutionary changes

6) Ancestors of modern whales developed a smaller inner ear than other mammals. The presence of the smaller inner ear is most likely the result of

   A. natural selection

   B. selective breeding

   C. asexual reproduction

   D. ecological succession

(Video) Stated Clearly - What is the Evidence for Evolution?
https://youtu.be/lIEoO5KdPvg

1) What are the two claims made by biological evolution?

2) What are four pieces of evidence that support the idea that whales are related to land mammals?

3) What is a possible reason for the small leg-like bones in whales' skeletons?

(Video) Stated Clearly - What is the Evidence for Evolution?
https://youtu.be/lIEoO5KdPvg

1) What are the two claims made by biological evolution?

First: All living things on earth are related. They evolved from a common ancestor.

Second: The evolution of living things is powered by natural processes. Things which can be studied and understood.

2) What are four pieces of evidence that support the idea that whales are related to land mammals?

Whales, just like land mammals but unlike fish:

- have placentas and give live birth
- They feed milk to their young
- They are warm blooded (which is extremely rare for a fish)
- and whales do not have gills, instead, just like us, they breath air with 2, fully developed lungs.

Whales don't seem to have noses like mammals do. Instead they breathe through blowholes coming out the tops of their heads. Some whales have two blowholes that almost look like nostrils, but dolphins and porpoises only have one. Surprisingly, if you look at their skulls, you find that the blowhole splits into 2 nasal passages inside the head. Could it be that the blowhole is actually a highly modified mammal nose?

Many whales have hair, just like land mammals.

Strangely, whales have arm, wrist, hand, and finger bones inside their front flippers.

Here we see a dolphin and a human embryo, side by side, at similar stages of development. Notice that they both have what look like arm buds, and leg buds. In humans, the leg buds grow to become legs. In whales, they grow for a while, but then stop, effectively fading away as the rest of the whale continues to grow.

These are all photographs of a common dolphin at different stages of development. Notice that early on, we see two nostril grooves on the front of the face, just like you'd expect in a puppy or a human.

The fossils of many ancient whale-like mammals have been found, and people continue to find more. Together, these fossils blur the line between 4 legged land mammals and fully aquatic whales, solidifying the idea that whales indeed, evolved from land creatures.

3) What is a possible reason for the small leg-like bones in whales' skeletons?

The hip bones of Maiacetus do seem sturdy enough to walk on land, but this animal is considered to be a whale for many reasons:

Their skeletons have all been found among fossils of sea-creatures

Their short legs combined with long flat fingers and toes, suggest they were strong swimmers with webbed hands and feet.

Name: _____

Date: _____

Writing about the Lesson

Darwin and other people in his time noticed similarities among different animals. In your journal entry, include details he might have noticed when he look at animal skeletons. Also include questions he might have asked himself as he thought at these animals.

Optional Activities

Sentence Combining Writing Practice - Evolution

Write one sentence that combines the sentences on the left side. You may want to use the words *for*, *and*, *nor*, *but*, or, *yet*, and *so*.

Simple sentences	**Combined sentences**
Whales live in the ocean. Fish live in the ocean. Whales are not fish.	Whales and fish both live in the ocean, but whales are not fish.
Whales are mammals. Whales live in the ocean.	
Whales have ulna, radius and carpal bones. Humans have ulna, radius and carpal bones. Lizards have ulna, radius and carpal bones.	
Whales lived in the water. Whales no longer needed their hind legs. Whales eventually lost their hind legs.	
Whales are big, sea animals. Whales evolved from small, land animals.	
Basilosaurid's legs are far too small for walking on land. Basilosaurid's legs may have been useful for mating or scratching away parasites and itchy skin.	

Whale DNA has been compared to sea lions. Whale DNA has been compared to fish. Whale DNA has been compared to the hippopotamus.	
The cells of different kinds of organisms are different. The cells of different kinds of organisms all share certain basic similarities.	
Aerobics is the type of exercise that requires your cells to use oxygen to produce energy from food. Aerobics burns more calories than other kinds of exercise.	
On his trip around the world, Darwin collected plants. On his trip around the world, Darwin collected animals. On his trip around the world, Darwin collected insects.	
Darwin saw a fossil. Darwin tried to understand how the fossil might be related to living animals.	
Charles Darwin found a fossil. The fossil was from a giant sloth. The fossil was in the Bahia Blanca Bay.	

It was December 27, 1831. Charles Darwin left England. Charles Darwin was on a boat. The boat was called the H.M.S. Beagle.	
All living things have cells. All living things breathe. All living things reproduce. Humans are living things.	
Vertebrates are animals with a backbone to support their bodies. Birds are vertebrates with wings and feathers. Fish are vertebrates with scales and skin.	
All living things need food. Animals eat plants or other animals. Animals are living things.	

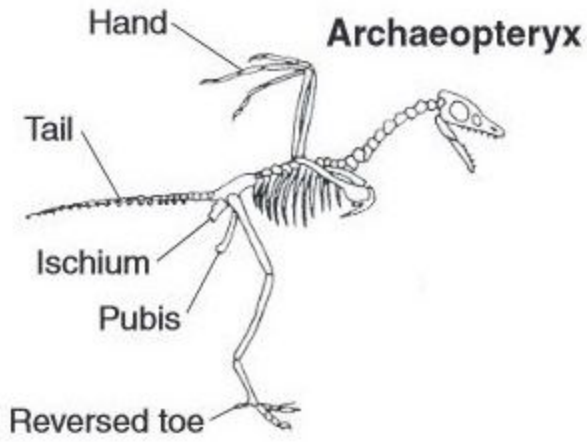
Sentence Combining Writing Practice - Evolution

There are many different ways to combine the sentences on the left. The examples on the right are not necessarily the best way of combining these sentences.

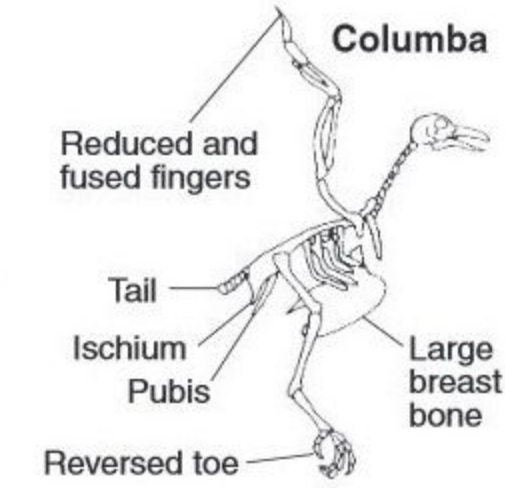
Simple sentences	**Combined sentences**
Whales live in the ocean. Fish live in the ocean. Whales are not fish.	Even though whales and fish both live in the ocean, whales are not fish.
Whales live in the ocean. Whales are mammals.	Whales live in the ocean, yet they are mammals.
Whales have ulna, radius and carpal bones. Humans have ulna, radius and carpal bones. Lizards have ulna, radius and carpal bones.	Whales, humans and lizards all have ulna, radius and carpal bones.
Whales lived in the water. Whales no longer needed their hind legs. Whales eventually lost their hind legs.	Whales lived in the water, so they no longer needed their hind legs and eventually lost them.
Whales are big, sea animals. Whales evolved from small, land animals.	Whales are big, sea animals, but they evolved from small, land animals.
Basilosaurid's legs are far too small for walking on land. Basilosaurid's legs may have been useful for mating or scratching away parasites and itchy skin.	Basilosaurid's legs are far too small for walking on land, yet they may have been useful for mating or scratching away parasites and itchy skin.

Whale DNA has been compared to sea lions. Whale DNA has been compared to fish. Whale DNA has been compared to the hippopotamus.	Whale DNA has been compared to seal lions, fish and the hippopotamus.
The cells of different kinds of organisms are different. The cells of different kinds of organisms all share certain basic similarities.	The cells of different kinds of organisms are different, yet they all share certain basic similarities.
Aerobics is the type of exercise that requires your cells to use oxygen to produce energy from food. Aerobics burns more calories than other kinds of exercise.	Aerobics is the type of exercise that requires your cells to use oxygen to produce energy from food, and burns more calories than other kinds of exercise.
On his trip around the world, Darwin collected plants. On his trip around the world, Darwin collected animals. On his trip around the world, Darwin collected insects.	On his trip around the world, Darwin collected plants, animals and insects.
Darwin saw a fossil. Darwin tried to understand how the fossil might be related to living animals.	Darwin saw a fossil and tried to understand how it might be related to living animals.
Charles Darwin found a fossil. The fossil was from a giant sloth. The fossil was in the Bahia Blanca Bay.	Charles Darwin found a giant sloth fossil in the Bahia Blanca Bay.

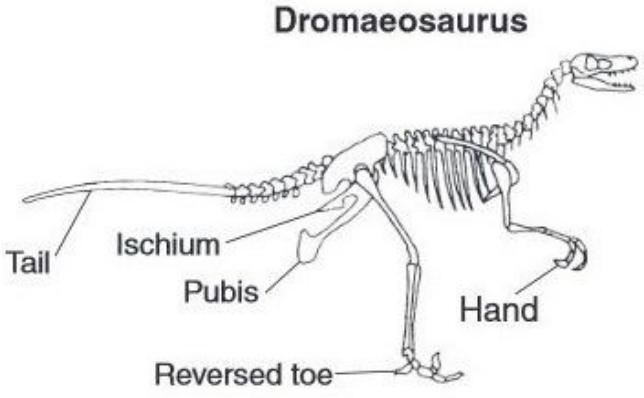
It was December 27, 1831. Charles Darwin left England. Charles Darwin was on a boat. The boat was called the H.M.S. Beagle.	On December 27, 1831, Charles left England on a boat called the H.M.S. Beagle.
All living things have cells. All living things breathe. All living things reproduce. Humans are living things.	Humans are living things that have cells, breathe and reproduce.
Vertebrates are animals with a backbone to support their bodies. Birds are vertebrates with wings and feathers. Fish are vertebrates with scales and skin.	Vertebrates are animals with a backbone to support their bodies; however, some have wings and feathers like birds and others have scales and skin like fish.
All living things need food. Animals eat plants or other animals. Animals are living things.	Like all living things, animals need food, so they eat plants and animals.



151 to 149 MYA



7 MYA to present day



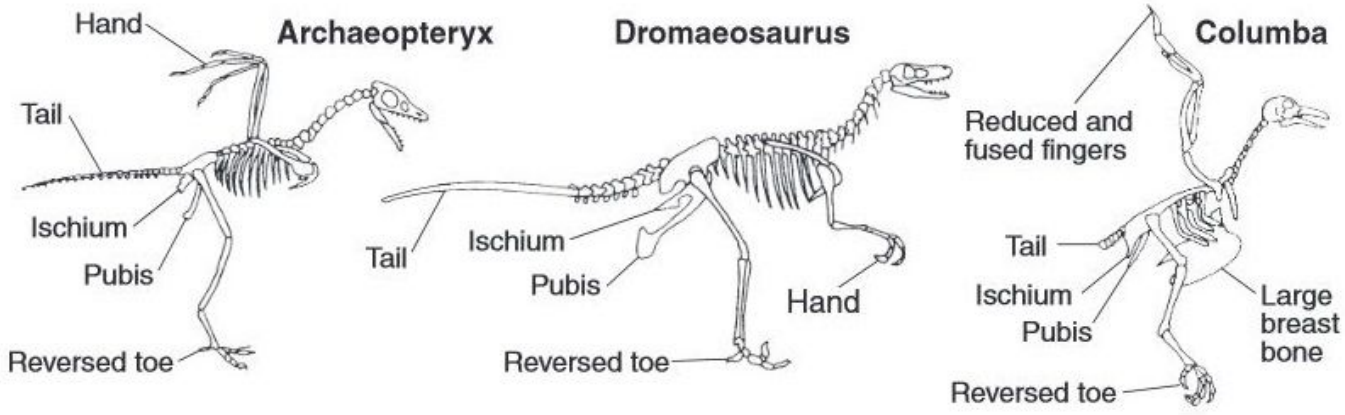
77 to 75 MYA

TASC Science Practice

Multiple Choice and Constructed Response

Circle the best answer from the choices below.

These are remains of three different organisms.



I. A study of these remains would indicate that these organisms have

A. identical food preferences

B. identical body sizes

C. structural similarities

D. habitat similarities

II. Which of these statements about the evolutionary history of Archaeopteryx, Dromaeosaurus and Columba is supported by the information above?

A. Archaeopteryx and Dromaeosaurus share a common ancestor with Columba.

B. Archaeopteryx and Columba share a common ancestor, but Dromaeosaurus and Columba do not.

C. Archaeopteryx and Dromaeosaurus share a common ancestor, but not with Columba.

D. Archaeopteryx and Dromaeosaurus do not share a common ancestor with each other or with Columba.

Part A. Give an example of two homologous structures in the skeletons of these three organisms. Write your answer in the space provided.

Part B. What conclusion could supported by the skeletal evidence above?