

MISSION 2 Fossils: Rocking the Earth

Introductory video: Fossils provide us with a historical record of life on Earth. There are many types of fossils, from extraordinary unaltered remains trapped in permafrost or amber, to subtle traces of past activities in the form of footprints and burrows. The fossils that we have found provide windows into the past and direct evidence of evolution. Before you start the first level in this mission, “Eating dinosaurs for dinner,” watch the introductory video and answer questions 1–2 below.

1. If these rock layers have been undisturbed, which layer is the oldest? Which layer is the youngest?
Mark your answer on the figure.



2. According to the video, fossils provide each of the following except:
- a. Examples of transitional species
 - b. A complete record of past life on Earth
 - c. Physical proof of extinction and speciation
 - d. Evidence that evolutionary change tends to be gradual



Eating dinosaurs for dinner: Has anyone ever told you that dinosaurs aren't extinct? It's true! They aren't. But how can that be? There are no *T. rexes* at the zoo, or *Triceratopses* roaming the plains. This level holds the key to understanding where today's dinosaurs are hiding—on our farms, in the trees, and on our dinner plates. Answer questions 3–5 below before you move on to the next level, “One small step.”

3. What is another name for the wishbone?

- a. Furcula
- b. Lucky bone
- c. Shoulder blade
- d. Sternum

4. Today, it's widely accepted that all of the two-legged meat-eating dinosaurs known as theropods—including *T. rex* and *Albertosaurus*—had at least very simple fuzzy feathers covering their bodies. According to the tree you built, what distinguishes the feathers of modern birds and *Archaeopteryx* from the feathers of other theropods?

- a. Barbs
- b. Fibers
- c. Filaments
- d. Shafts

5. A clade is a fancy word for any group in a phylogenetic tree that includes an ancestor and all of its descendants. A simplified dinosaur tree is to the right.

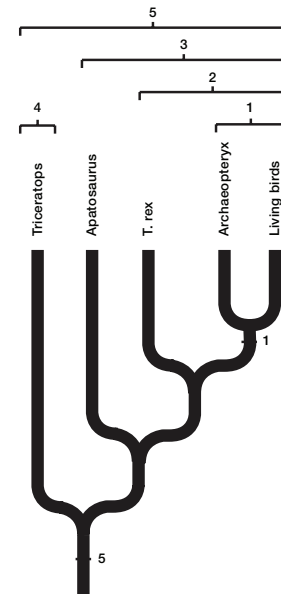
Imagine that you have a pair of scissors and can cut the tree. You can tell a group is a clade because it would only take one “snip” to make the group “fall off” the tree. Five different clades have been marked on the tree with brackets.

The clade marked 1 is clade Aves—the birds.

The clade marked 2 is clade Theropoda—the theropods.

Clades 2 and 3 are the two major groups of dinosaurs—clade Saurischia and clade Ornithischia.

Finally, clade 5 is clade Dinosauria—the dinosaurs.



- a. Mark on the tree using numbers 2–4 where you can “snip” off each clade. Numbers 1 and 5 have been done for you.
- b. *Triceratops* belongs to two of the marked clades on this tree: 4 and 5. This means that *Triceratops* is both an ornithischian (clade 4) and a dinosaur (clade 5). Which clades do birds belong to?
- c. Use your answer to part b to explain why birds are dinosaurs.

One small step: There have been a number of dramatic transitions over the history of life. After a few billion years of nothing but single-celled organisms, multicellular life developed. Organisms evolved tissues and organs. Plants developed spores, flowers, and seeds. Animals developed complex neurological systems and external and internal skeletons. And, of course, bacteria evolved novel methods to live just about everywhere on Earth. One of these great transitions is the subject of this level. Have you ever heard of an animal called *Tiktaalik*? How about *Acanthostega*? They are but two of the many remarkable fossils we have that document the transition of animal life from water to land. Answer questions 6–9 below before you move on to the next level, “Origin of whales.”

6. For an animal that lives in shallow water, what is the advantage of having eyes on the top of its head?
7. We know that *Tiktaalik* is more closely related to *Acanthostega* than it is to *Eusthenopteron* because *Tiktaalik* and *Acanthostega*:
- Both lacked digits
 - Both lacked strong forearms
 - Both had a humerus, radius, and ulna
 - Both had eyes on the top of their heads
8. *Ichthyostega* is a 370-million-year-old fossil from Greenland. *Ichthyostega* had digits, eyes on the top of its head, and strong, armlike bones. It also had no gills and a reduced tail—traits it had in common with *Tulerpeton*. *Acanthostega*, *Eusthenopteron*, and *Tiktaalik* all had gills and full tails. Use the abbreviations provided to draw a phylogenetic tree that includes *Ichthyostega*.

A = <i>Acanthostega</i>	D = digits
E = <i>Eusthenopteron</i>	E = eyes on top of a flat head
I = <i>Ichthyostega</i>	G/T = loss of gills and a reduced tail
Tu = <i>Tulerpeton</i>	S = strong, armlike bones
Ti = <i>Tiktaalik</i>	

9. Animals commonly called reptiles, amphibians, birds, and mammals are all tetrapods—a term that means “four feet.” The transition from water to land is fascinating to scientists in part because it’s our history—the transition documents the evolution of tetrapods, and humans are tetrapods. Tetrapods form a clade. Which of the following is true of tetrapods?
- Tetrapods are more complex than non-tetrapods.
 - Tetrapods are more evolved than non-tetrapods.
 - Tetrapods are more closely related to each other than to non-tetrapods.
 - All of the above



Origin of whales: In the previous level, you looked at the transition from water to land and the evolution of tetrapods. Several groups of tetrapods went on to make the reverse trip—they headed back to the water.

In this level, you'll put together a tree that summarizes some of the changes that occurred as a group of mammals, closely related to the modern-day hippopotamus, returned to the sea. Answer questions 10–12 below before you move on to Mission 3, "DNA Spells Evolution."

10. When did whale ancestors begin living full time in the water?

- a. After they nursed under water
- b. After they lost their hind legs
- c. Before they evolved gills
- d. Before they began eating a carnivorous diet

11. Whales are tetrapods—but living whales do not have four limbs. What is a more accurate way to describe tetrapods?

- a. Animals that have at least two limbs
- b. Animals that descended from a four-limbed ancestor
- c. Animals that have four limbs at some point in their lives
- d. Animals that evolved the ability to survive without limbs

12. When two groups of organisms independently evolve similar adaptations, it's called convergent evolution. Sharks and whales both have streamlined bodies and tail flukes. How do we know that these similarities are because of convergent evolution? Hint: Whales are tetrapods. Are sharks?

