Geological and Fossil Evidence

Scientists study clues left behind in ancient rocks and discover traces of organisms that have long been extinct. Fossils are an important piece of evidence used to determine the evolutionary history of a species.

Geological Evidence

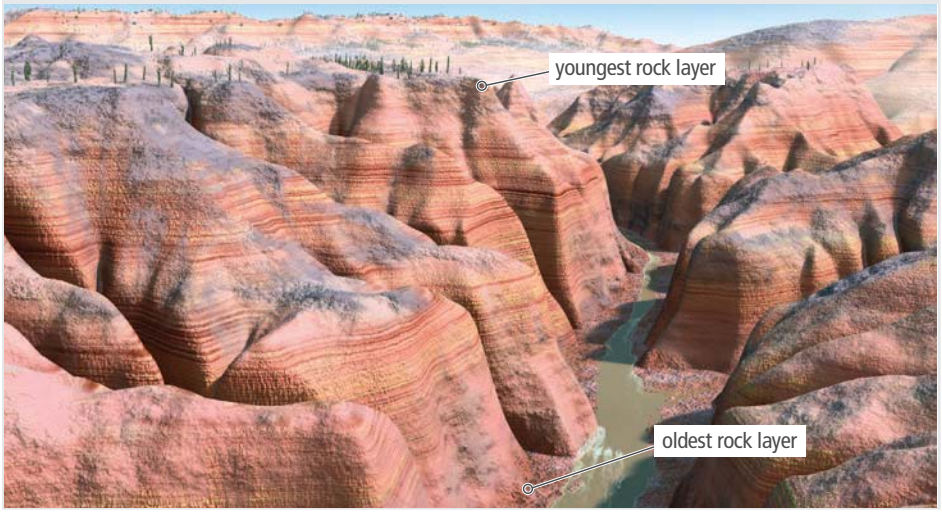
The age of Earth was a key issue in the early debates over evolution in the early 19th century. The common view was that Earth was created about 6,000 years earlier, and that since that time, neither Earth nor the species that lived on it had changed.

Georges Cuvier, a French zoologist of the late 1700s, did not think that species could change. However, his observations of fossil remains convinced him that species could go extinct. He found that fossils in the deepest layers of rock were quite different from those in the upper layers, which were formed by more recent deposits of sediment. He supported the theory of catastrophism which states that natural disasters such as floods and volcanic eruptions have happened often during Earth's long history. These events shaped landforms and caused species to become extinct in the process.

In the late 1700s, the Scottish geologist James Hutton proposed that the changes he saw in landforms resulted from slow changes over a long period of time, a principle that became known as gradualism. He argued that the layering of soil or the canyons formed by rivers cutting through rock did not result from large-scale events. He thought, rather, that they resulted from slow processes that had happened in the past.

One of the leading supporters of the argument for an ancient Earth was the British geologist Charles Lyell. In *Principles of Geology*, published in the 1830s, Lyell expanded Hutton's theory of gradualism into the theory of uniformitarianism. This theory states that the geologic processes that shape Earth are uniform, or remain the same, through time. Uniformitarianism combines Hutton's idea of gradual change over time with Lyell's observations that such changes have occurred at a constant rate and are ongoing. Uniformitarianism soon replaced catastrophism as the favored theory of geologic change.

FIGURE 9: This model shows evidence of slow, gradual change over time.



Explain Why are the concepts that Earth undergoes change and is billions of years old important for evolutionary theory?

Cause and Effect

Explain How do the geological features shown in Figure 9 support the claim that slow, gradual changes add up over long periods of time to cause great change?

Fossil Evidence

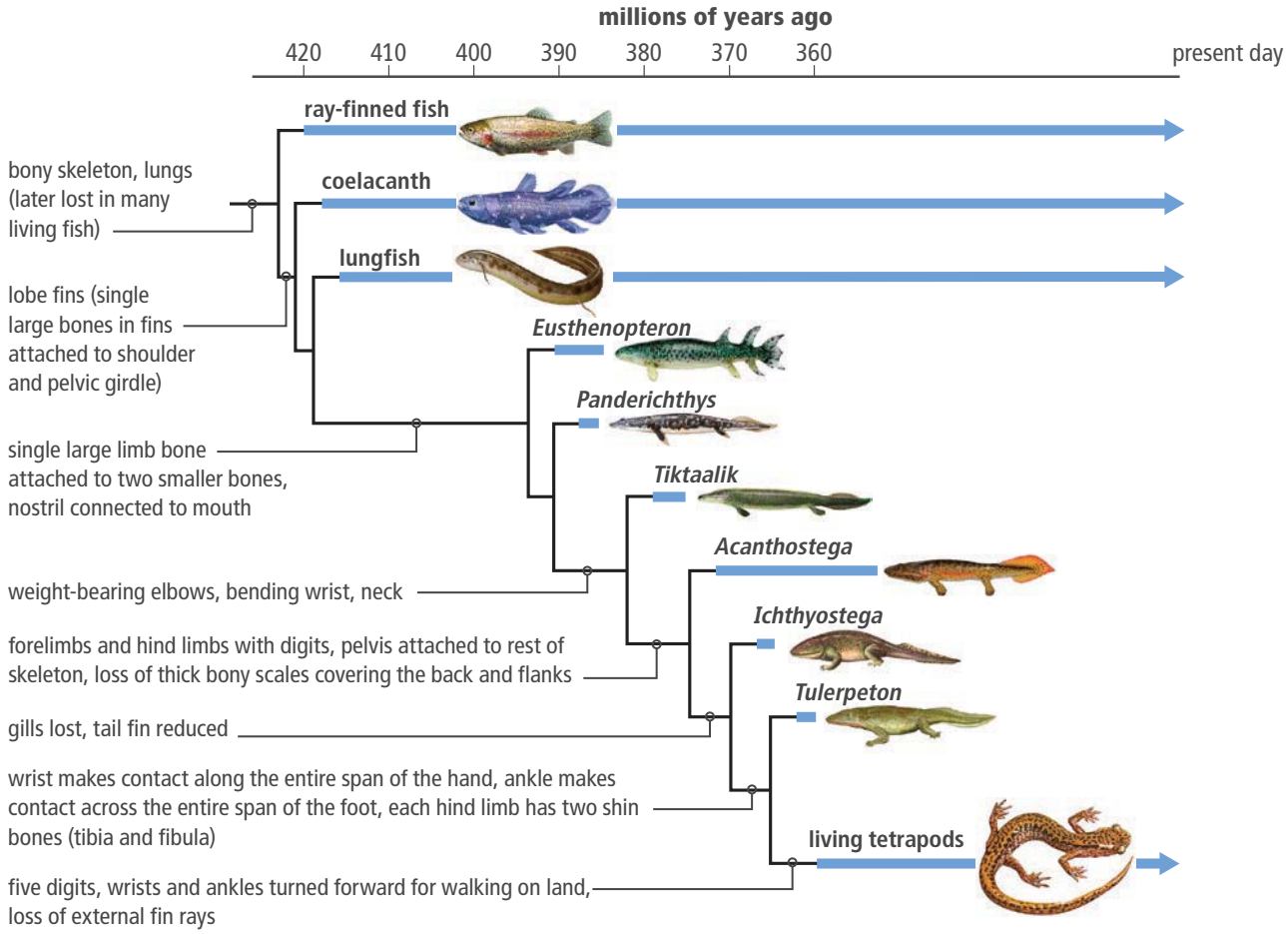
A fossil is the preserved remains of an organism, or the trace evidence of an organism's existence in the past. Most fossils form in sedimentary rock, which is made by many layers of sediment, or small rock particles. The best environments for any type of fossilization include wetlands, bogs, and areas where sediment is continuously deposited, such as river mouths, lakebeds, and flood plains.

Layers of rock form gradually over long periods of time, with more recent layers typically on top of older layers. Fossils that differ from each other slightly and are embedded in different layers of rock provide evidence for gradual change in species over time. The conditions needed for an organism's body to fossilize are rarely met. An organism's remains may be eaten by scavengers, it may decompose before it has time to fossilize, or it may simply be wiped away by erosion. Because of this, the fossil record will always be incomplete.

Scientists have been able to fill in some of these gaps by finding fossils of transitional species. These "missing links" demonstrate the evolution of traits within groups as well as the common ancestors between groups. For example, *Tiktaalik roseae* is a transitional species between fish and tetrapods. Figure 10 shows where *Tiktaalik* fills in the gap in the evolutionary history of fish and tetrapods.

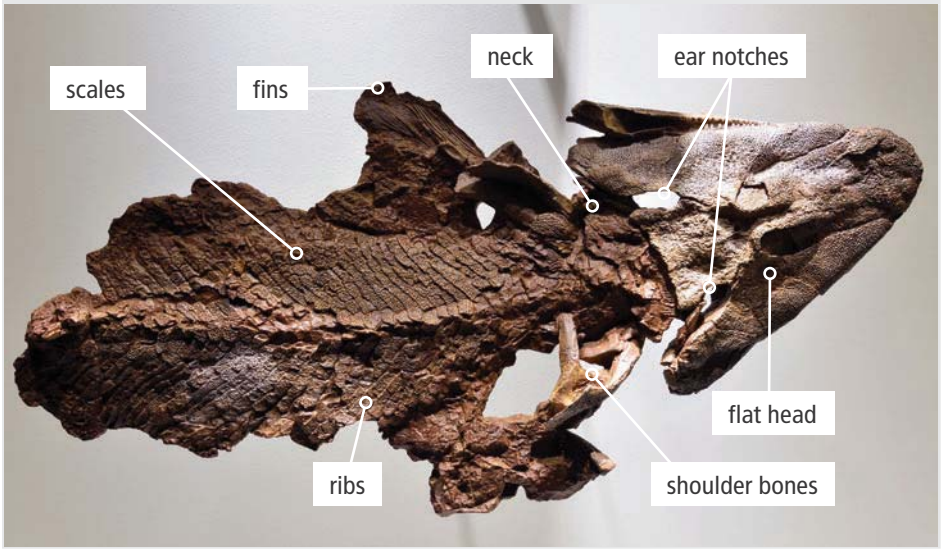
Collaborate With a partner, create a chart to explain how the traits described in Figure 10 would have helped the ancestors of living tetrapods adapt to walking on land.

FIGURE 10: This diagram shows the evolutionary relationships between ancient fishes and modern-day tetrapods.



Source: Zimmer, Carl, *The Tangled Bank*, Roberts & Company, 2009, as quoted by "The origin of tetrapods." Understanding Evolution http://evolution.berkeley.edu/evolibrary/article/evograms_04.

FIGURE 11: Fossil remains of *Tiktaalik,* a transitional species that lived about 370 million years ago, has both fish and tetrapod characteristics.



Analyze How do the presence of gills and lungs, as well as a bone structure that is homologous to that of tetrapods, support the idea that *Tiktaalik* fills in the gap between aquatic and land-dwelling species?

As you can see in Figure 11, *Tiktaalik* has both fish and tetrapod qualities. It has fins and scales like a fish. It also has the beginnings of limbs, including digits, proto-wrists, elbows, and shoulders, along with a functional neck and ribs similar to that of a tetrapod. Its discovery in 2004 helped to fill in the gap in the fossil record between early fish and the first land-dwelling species that evolved about 25 million years later. But that's not all it does. The structure of a recently discovered pelvic bone from *Tiktaalik* suggests that this creature used its hind legs in a more significant way than previously thought. The finding contradicts the previously held idea that primitive land animals used only their front legs to drag themselves across an ancient beach.

By studying the fossils found in individual rock layers, scientists can determine the approximate age of each fossil. Then by comparing one fossil to another, or examining fossils from different geographic areas, scientists can determine details about the environment in which each species lived.

Closer examinations of fossils and comparisons to living species can indicate anatomical and physiological similarities. Through analysis of the fossil record, we can begin to put together a clearer picture of a species' evolutionary history.

FIGURE 12: *Archaeopteryx* and modern-day bird skulls share common characteristics.

a *Archaeopteryx* skull replica

b Chicken skull

Explain Look at the *Archaeopteryx* and chicken skulls. What are the similarities, and what are the differences? How does the fossil evidence support the idea that birds share a common ancestor with dinosaurs?