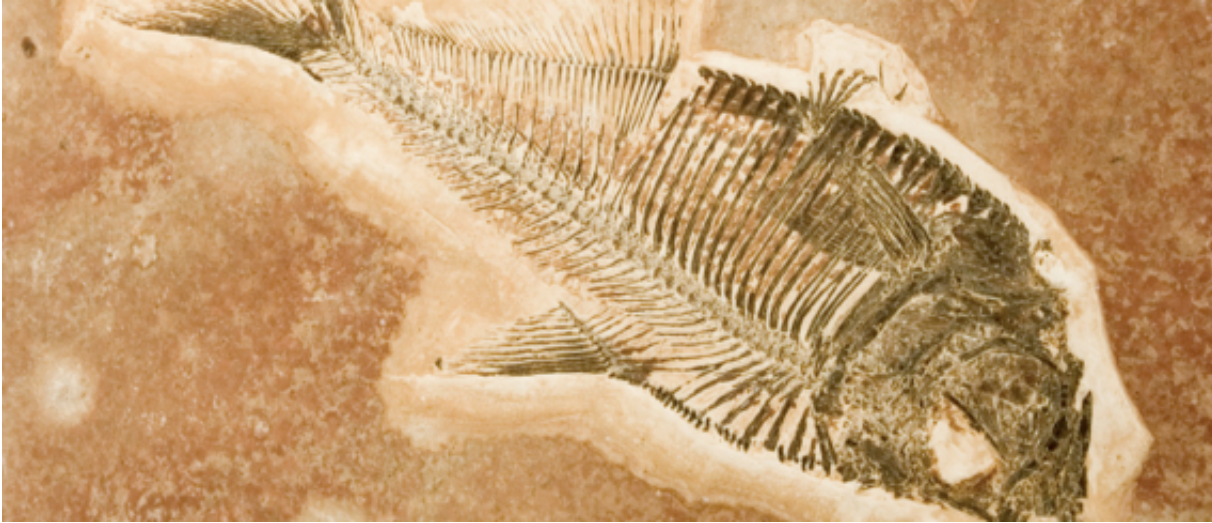


# What does the fossil record show?



## Introduction

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The fossil record provides a unique view into the history of life by showing the forms and features of species through time. This is particularly important for evolution because it shows the changes in species across long periods of the Earth's history; it provides insight into the evolutionary tree.

## Evidence of Gradual Change

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Organisms have changed significantly over time. In rocks more than 1 billion years old, only fossils of single-celled organisms were found. Moving to rocks that are about 550 million years old, fossils of simple, multicellular animals can be found. At 500 million years ago, ancient fish without jawbones surface; and at 400 million years ago, fish with jaws are found. Gradually, new animals appear: amphibians at 350 million years ago, reptiles at 300 million years ago, mammals at 230 million years ago and birds at 150 million years ago.<sup>1</sup> Even within these groups, major changes have occurred through time. For example, dinosaurs dominated the reptile fossils from 230 to 65 million years ago; early birds had teeth and tails; and early mammals were no larger than mice.<sup>2</sup> As

the rocks become more and more recent, the fossils look increasingly like the animals we observe today.

When considering what the fossil record tells us about evolution, an important question is whether the fossil record supports the evolutionary claim that new species arise through gradual change. In *Coming to Peace With Science*, biologist Darrel Falk examines this key aspect of evolution in relation to the fossil record. The following four examples from Falk's discussion indicate the fossil record does support evolution and, more specifically, new species arise through gradual change. (See Chapter 4 of *Coming to Peace With Science*.)

## The Transition to Land: Sea Creatures to Land Animals

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Fossils of land animals, or *tetrapods*, first appear in rocks that are about 370 million years old. In older rocks, only sea creatures are found. The most notable feature of these new land animals is their legs, located in the same place as the fins on sea creatures. Until recently, there was no clear connection between sea creatures and land animals. All of the known fossils seemed to be clearly one or the other. But in 1998, scientists found a fossilized fin of just the right age — 370 million years old — with eight digits similar to the five fingers humans have on their hands and distinct humerus, radius and ulna like an early tetrapod, as shown in Figure 1.<sup>3</sup>

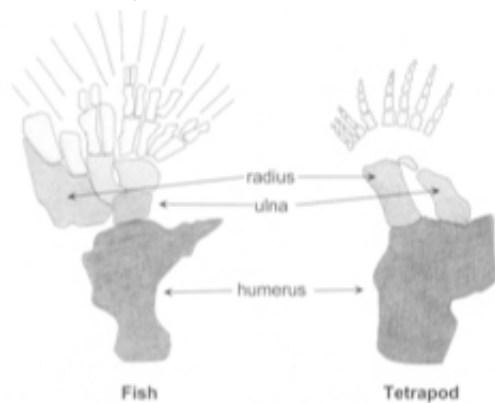


Figure 1: An Illustration of the fossilized fin found in 1998. Its resemblance to a Tetrapod is an indication of gradual evolutionary change from sea creatures to land animals. Source: Image is used by permission from Darrel R. Falk, *Coming to Peace with Science: Bridging the Worlds between Faith and Biology* (Downers Grove, IL: InterVarsity Press, 2004), 113.

However, the fin was undoubtedly that of a fish, which means this fossil is strong evidence of a transitional form. The fossil's eight digits are particularly supportive of evolutionary change. With few exceptions, terrestrial vertebrates have no more than five digits on their limbs. The only other exceptions to the five digit rule occur during a narrow time period about 370 million years ago when land animals first appeared on the scene. This is a strong indication the exceptions to the five digit rule are examples of evolutionary, gradual change.<sup>4</sup>

Another transitional form, called *Tiktaalik*, was discovered in northern Canada in 2006. *Tiktaalik* had forelimbs with the properties of fins that were also able to support weight on land. *Tiktaalik* was found in a rock formation that was approximately 375 million years old, in line with same narrow time period mentioned above.<sup>5</sup>

## Turtles

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Turtles are a good example of transitional forms from later dates in the fossil record. Turtles have a distinct body structure — namely their characteristic protective shell. Compared to other vertebrates, this body plan is very old and has experienced relatively little change. Fossilized turtles first appear 210 million year old rocks. At 255 million years old, rocks reveal fossils of creatures with small, bony plates in the center of their backs.<sup>6</sup> These plates were not large enough to protect and insulate like a turtle shell. They are thought to have given structural support to the backbone. At 248 million years old, fossils reveal a species with bony, disconnected plates covering most of its back and another species with fused plates covering the entire back. These plates were similar, though not identical, to standard turtle shells. The species also had other skeletal features similar to turtles. The appearance of these early turtle-like fossils just before the true turtle fossils appear points to the gradual evolution of turtles.

## From Reptiles to Mammals

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Fossil records show a transition from reptiles to mammals during the same time period as the transitional turtle fossils. Mammals first appeared in the fossil record about 230 million years ago, nearly 70 million years after reptiles first appeared. One group of reptiles, the *cynodonts*, first appeared about 260 million years ago and became increasingly mammal like in more recent fossils — circa 245 million years ago. This change can be seen most clearly in the bone structure of the ear, as illustrated in the image below.<sup>8</sup>

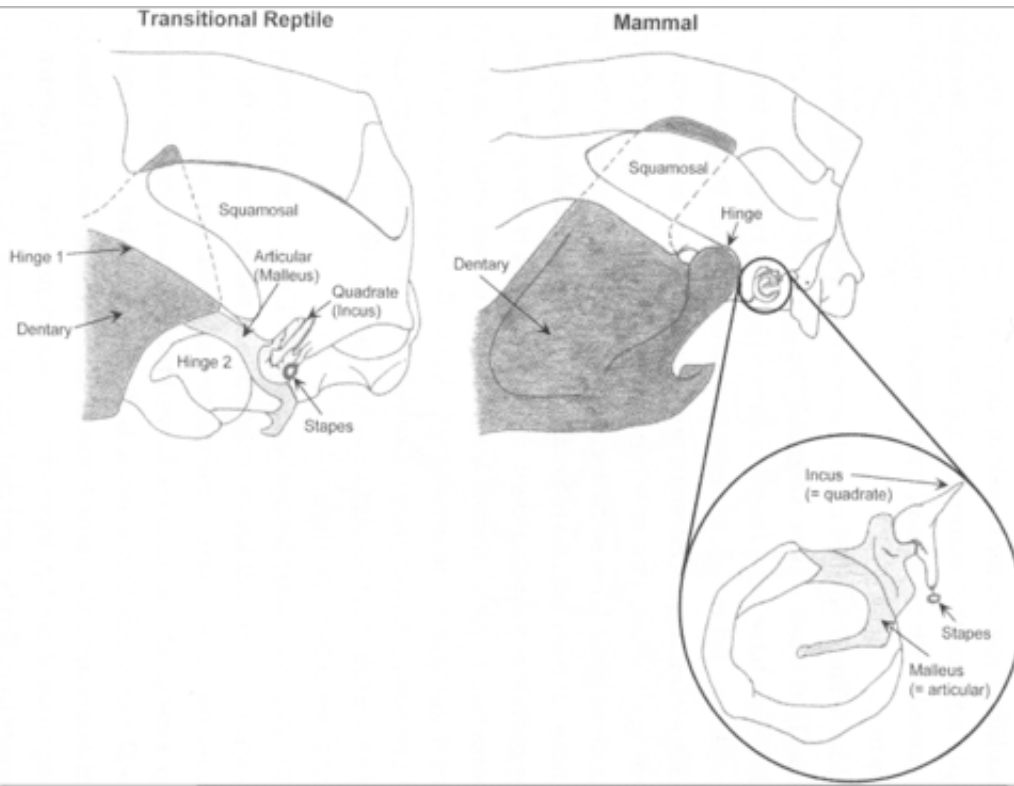


Figure 2: As shown in the image

above, transitional fossils of *Cynodonts* had two jaw hinges. These fossils date from a time when the dentary and squamosal bones were beginning to take over the role of jaw hinge (hinge #2). This allowed the articular and quadrate bones to evolve into the second and third bones of the mammalian ear, as shown on the right. Source: Image used by permission from Darrel R. Falk, *Coming to Peace with Science: Bridging the Worlds between Faith and Biology* (Downers Grove, IL: InterVarsity Press, 2004), 119.

Mammalian ears have three special bones: the malleus, incus and stapes (shown in the bottom right of the image, and known to school children as the hammer, anvil and stirrup in human ears). These detect vibrations and allow hearing. Mammals also have a jaw with two bones that make up the hinge: the dentary and squamosal bones. *Cynodonts*, on the other hand, had only one bone in their middle ear: the stapes. Their jaw hinge was formed by two different bones located close to the stapes: the articular and quadrate bones.

Scientists found a species of *cynodonts*, dating to just before the emergence of mammals, that had a double jaw hinge, or dentary-squamosal, like that of a mammal. *Cynodont* fossils that dated back even further had an articular-quadrate hinge located very close to the ear drum. The articular-quadrate appears to have served two roles: to function as a hinge and to transmit sound vibrations. The articular and quadrate bones seem to have transitioned slowly into the ear, as the dentary and squamosal took over for the jaw. No other fossils have been found that share a similar structure to the transitional *cynodonts* and date back before the time of mammals. Likewise, soon after mammals appeared, these *cynodonts* became extinct. This timing implies that the *cynodont* fossils record the transition from reptiles to mammals. The timelines fossil records provide are strong evidence of gradual, evolutionary change.<sup>9</sup>

# Whales

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Fossilized whales provide yet another example of gradual change from one species to another. Whales live in the water, but they are also mammals. Although land animals are believed to have evolved from water animals, whales are thought to have evolved from land animals at a later time.

Recently, a 52-million-year-old whale fossil, *Pakicetus*, was found in Pakistan. It was clearly a small, wolf-sized whale, but it did not have the characteristic fat-pad, a structure that allows the whale's jaw vibrations to be used for hearing. Also, its teeth were much like those of the terrestrial animals already thought to be related to whales. Scientists then found fossils of a more recent — 40 million years ago — and larger — 50 feet — specimen of *Basilosaurus*. Appearing later in the fossil record than *Pakicetus*, this whale showed less resemblance to terrestrial animals, although it still had a small but well-formed mammalian limb. Not long after the discovery of this specimen, the fossil record of a new species, which had full length hind limbs and a tail, was found.<sup>10</sup> According to its age and structure, this new species, *Ambulocetus*, appeared to be a transition species between *Pakicetus* and *Basilosaurus*.<sup>11</sup> More and more fossils continue to surface in this region of Pakistan, which further illustrate the gradual change from land animals to whales.

## Transitional Forms: Few and Far Between

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These examples all illustrate an important point: transitional forms occur just when one might expect to see a change from one body type to another. However, a common objection is that few transitional fossils have been discovered, thus many lineages cannot be traced smoothly.

There are several reasons for these gaps in the fossil record. First, fossilization is a very rare event. In total, scientists have unearthed only 250,000 fossil species. Considering the vast number of species throughout history, this is a remarkably small fraction — the 10 million species alive today constitute about 1 percent of all the species that existed. This is partly because many organisms do not leave any trace. Typically, in order to leave a fossil remnant, the organism needs to have hard, bony parts, and the organism's body must be buried quickly in sediment.

But even among the 250,000 unearthed fossil species, there are still few transitional forms. One explanation relates to the fact that transitional species tend to appear in small populations, where rapid changes in the environment can provide a stronger evolutionary drive. A small population may produce a higher proportion of transitional species, but by virtue of its small size it would yield fewer fossils.

For example, Falk gives the hypothetical example of two bird populations: a small island community of 100 birds and a large mainland group of 100,000.<sup>12</sup> On the island, one bird undergoes a genetic change that gives it a longer beak, enabling it to produce an average of two offspring instead of one. The long beak increases the survival rate and the likelihood of reproduction via natural selection. Its two long-beaked offspring would be more likely to survive than the other birds in the community, yielding 4 percent of the population with long beaks in the following generation. In a relatively short time, the long-beaked birds would take over the population. If these same changes took place on the mainland, the first long-beaked bird would leave two offspring, which means two out of one hundred thousand birds would inherit long beaks. Assuming the same reproduction rate, later generations would include four, eight and then 16 birds with longer beaks. However, in a community of 100,000, the percentage of long-beaked birds would be much lower. Therefore, it would take much longer for this change to affect the entire population. This delay is further compounded because many genetic changes are recessive. This means a species' offspring must inherit two copies of the gene in order for it to be expressed, which requires that a long-beak can be found only among birds whose parents both carried the long-beaked gene. Due to the increased likelihood of inbreeding in smaller populations, it is far more probable that a bird in this community will have two copies of the same gene.<sup>13</sup> Whereas, in a larger population, a long-beaked bird is more likely to end up mating with a short-beaked bird, and the long-beak trait would not be passed on.

Finally, because fossilization itself is a rare event, smaller populations are sure to produce fewer fossils. Because this is where many of the transitional species are expected to develop, this makes the fossilization of transitional species even more unlikely. Given all of the above constraints, the fact that transitional species have been found at all is remarkable, and it offers further support of gradual, evolutionary change.

### **Consulted Experts:**

*The BioLogos Foundation is grateful for the assistance of [Darrel Falk](#) in drafting this response.*

## Notes

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1. Darrel R. Falk, *Coming to Peace with Science: Bridging the Worlds between Faith and Biology* (Downers Grove, IL: InterVarsity Press, 2004), 83-84.
2. *Ibid.*, 84.
3. Image from Falk, 113.
4. *Ibid.*, 111-115; E. B. Daeschler and Neil Shubin, "Fish with Fingers?" *Nature* 391 (1998): 133;

- M. I. Coates and J. A. Clack "Fish-like Gills and Breathing in the Earliest Known Tetrapod" *Nature* 352 (1991): 234-36; M. I. Coates, J. E. Jeffrey, and M. Ruta, "Fins to Limbs: What the Fossils Say. *Evolution and Development* 4 (2002): 390-401.
5. E. B. Daeschler, N. Shubin, and F. Jenkins, "A Devonian tetrapod-like fish and the evolution of the tetrapod body plan," *Nature* 440 (2006): 757-763.
  6. Falk, *Coming to Peace with Science*, 103.
  7. Falk, *Coming to Peace with Science*, 103; based on Michael Lee, "The Turtle's Long-lost Relatives," *Natural History* 103 (1994): 63-65.
  8. Image taken from Falk, 119. Taken from F. H. Pough, J. B. Heiser, and W. N. McFarland, *Vertebrate Life*, 4th ed. (Upper Saddle River, NJ: Prentice Hall, 1996), 607.
  9. Falk, *Coming to Peace with Science*, 115-120; F. H. Pough, J. B. Heiser, and W. N. McFarland, *Vertebrate Life*, 4th ed. (Upper Saddle River, NJ: Prentice Hall, 1996), 607; M.J. Benton, *Vertebrate Paleontology: Biology and Evolution*, (London: Unwin Hyman, 1990), 228-231; E.H. Colbert, M. Morales, and E.C. Minkoff, E.C., *Colbert's Evolution of the Vertebrates: A History of Backboned Animals Through Time*, (New York: Wiley-Liss, 2001), 274-277; T.S. Kemp, *The Origin and Evolution of Mammals*, (New York: Oxford University Press, 2005), 75-78.
  10. Falk, *Coming to Peace with Science*, 107-109; for a general summary, see K. Wong, "The Mammals That Conquered the Seas," *Scientific American* 286, no. 5 (2002): 70-79. For a technical discussion see J.G.M. Thewissen, E. M. Williams, L. J. Roe, and S. T. Husain, "Skeletons of Terrestrial Cetaceans and the Relationship of Whales to Artiodactyls," *Nature* 413 (2001): 277-81; P.D. Gingerich, M. ul Haq, I. S. Zalmout, I. H. Khan and M. S. Malkani, "Origin of Whales from Early Artiodactyls: Hands and Feet of Eocene Protocetidae from Pakistan," *Science* 293 (2001): 2239-42; and J.G.M. Thewissen, Lisa Noelle Cooper, Mark T. Clementz, Sunil Bajpai, and B. N. Tiwari, "Whales originated from aquatic artiodactyls in the Eocene epoch of India," *Nature* 450 (2007): 1190-1194.
  11. Paleontologists can never be confident that the species identified in a fossil is the transitional species in a lineage. All they ever know is that the specimen they identified is probably closely related to the actual transitional species.
  12. Falk, *Coming to Peace with Science*, 126-130.
  13. Falk, *Coming to Peace with Science*, 127.

## Further Reading

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# Books

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- Falk, Darrel R. Coming to Peace with Science: Bridging the Worlds between Faith and Biology. Downers Grove, IL: InterVarsity Press, 2004.
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