Lesson 12: Dinosaur Extinction

Written by Victoria Arbour, W. Scott Persons, Philip Currie, and Eva Koppelhus

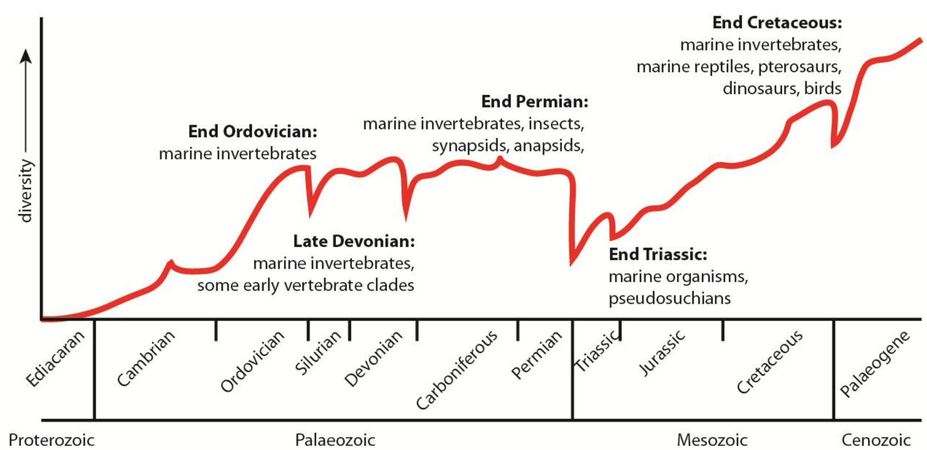
Learning objective for lesson 12: Students will be able to describe the end-Cretaceous extinction event, and provide examples of vertebrate groups that both persisted and died out during the event

Learning objective 12.1: Compare background extinction to mass extinctions.

Species that are still present today are called **extant** species. Species whose members have all died off are called **extinct** species. Naturally, the number of extant species is only a tiny fraction of the huge number of species that are now extinct. As environments gradually change and species evolve and compete, the extinction of some species is an inevitable result.

At any time in the history of life, it is usual for some species to be going extinct. However, certain dramatic environmental changes can trigger the extinction of many species all at nearly the same time and across the entire planet. When such a sudden and global loss of species occurs, it is called a mass extinction event.

Palaeontologists generally recognize five major mass extinctions. The End Ordovician mass extinction affected only marine organisms, but at that time terrestrial organisms had only just begun to evolve. The Late Devonian mass extinction was also largely limited to marine organisms, including some early vertebrate clades. As discussed in Lesson 11, the End Permian mass extinction saw the largest loss of diversity in all of Earth's history. Marine invertebrates were decimated, and this was the



This figure is modified from a graph of "Family"-level diversity through time by Jack Sepkoski and David Raup published in 1982 – it is often referred to as the Sepkoski curve. Newer data has refined the graph somewhat, but the overall pattern still stands. Diagram by V. Arbour.

largest mass extinction of insects. On land, the synapsids were hard hit, as were the anapsids (which we have not discussed much in this course, but which included large and small herbivores and some aquatic species). The End Triassic mass extinction saw the extinction of most lineages of pseudosuchian archosaurs, as well as many of the synapsids that had survived the End Permian extinction, and also affected marine life.

The last of the "Big 5" extinctions was the End Cretaceous. The End-Cretaceous Extinction event occurred roughly 66 million years ago and killed all non-avian dinosaurs. However, dinosaurs were not the only casualties of this extinction. In the oceans, large marine diapsids, called mosasaurs and plesiosaurs, died out, as did many varieties of corals, several forms of plankton, and ammonites (relatives of modern squids and octopi). Pterosaurs went extinct as well. Although birds ultimately survived, many types of Cretaceous birds (including hesperornithiform and enantiornithiform birds) perished. Land plants also lost many species in the extinction, and insect diversity fell.

Mammals, turtles, crocodiles, amphibians, and fish all made it through the End-Cretaceous Extinction, although many of the larger species in all these groups did not. Generally, it seems that large animals and photosynthetic organisms were the most likely to die off. Small animals, and particularly those that were semiaquatic, had the best chance of surviving. However, not all groups of animals that survived the End Cretaceous extinction are still around today. Champsosaurs are a good example: these crocodile-like aquatic diapsids (completely unrelated to crocodilians, and another good example of convergent evolution at work) survived the End Cretaceous mass extinction, only to go extinct during the early Miocene (about 20 million years ago).

Top, *Mosasaurus*, a giant marine lizard; middle, *Quetzalcoatlus*, a giant pterosaur; and bottom, *Hesperornis*, a flightless aquatic bird. *Mosasaurus* by D. Bogdanov and used with the GNU Free Documentation license. *Quetzalcoatlus* by D. Bogdanov and released into the public domain. *Hesperornis* by N. Tamura and used with the GNU Free Documentation license.

***Champsosaurus natator* in the University of Alberta Paleontology Museum. Photo by V. Arbour.**

Extinct animals do not include only prehistoric species that died out millions of years ago – many species have also gone extinct more recently. In some of the most recent examples of extinction, species have been eliminated through the actions of humans. For example, the thylacine (also called the Tasmanian tiger or Tasmanian wolf) was a large carnivorous marsupial that went extinct sometime went the last individual died in a zoo in 1936. The Carolina parakeet, the only species of parrot native to the USA, went extinct in 1918. Perhaps one of the most famous examples, the passenger pigeon, went extinct in 1914 even though there were billions of passenger pigeons only a few decades prior. The extinction of these species was the result of intense hunting and habitat loss, both caused by humans. Many animals today are on the verge of extinction, with severely depleted populations. Although deliberate hunting does not play as much of a role in the depletion of modern animal populations, habitat loss and pollution are significant contributors to the extinction of different species. Based on the current rate of species extinction, many biologists have argued that the earth is presently in the middle of a sixth mass extinction event. This new mass extinction is being brought about by sudden global climactic change and large-scale ecosystem destruction and degradation (the results of human activities).

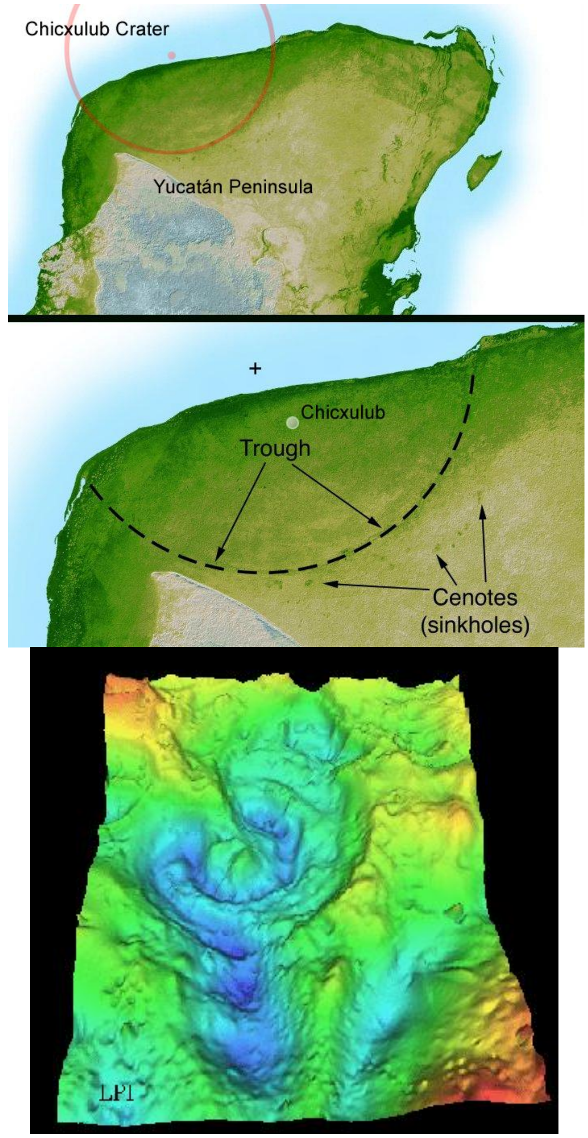
Learning objective 12.5 – Describe geological features associated with meteorite impacts.

In 1979, an Italian stratigrapher was studying rock layers at the boundary of the Cretaceous and Paleogene periods and noticed a strange thin layer of grey clay. Later, this same grey layer began to be discovered at the Cretaceous/Paleogene boundary all over the world and in very different formations. Close inspection of the grey clay layer revealed that it had high concentrations of iridium. **Iridium** is a rare element on earth, but it is a common component of meteorites. That was not all: the layer was also rich in tektites and shocked quartz. **Tektites** are tiny pieces of rock that have been melted and then cooled. **Shocked quartz** is a form of the mineral quartz with a unique internal structure that can only be created by exposure to a powerful shockwave, like those created by a nuclear explosion or a meteorite impact.

Tektite specimens in the University of Alberta Geology Collection. By W Scott Persons.

Both tektites and shocked quartz are telltale signs of a meteorite impact, but to spread iridium, tektites, and shocked quartz all across the globe would have required either an enormous shower of large meteorites or … a single tremendous meteorite impact. Could a meteorite impact have been responsible for the End Cretaceous mass extinction? The search was on for a giant crater.

For many years, no such crater was found. Then, geologists working near the town of Chicxulub in Mexico's Yucatán Peninsula noticed a peculiar pattern of **cenotes**, or limestone sinkholes. The cenotes were arranged in a crescent shape many miles long. Each end of the crescent seemed to terminate at an edge of the peninsula. Investigation revealed that the cenotes were caused by a displaced portion of a limestone layer that had been pushed upwards, and that the structure did not actually end at the edges of the peninsula. Instead, it continued along the ocean floor and was actually a huge continuous ring over 180 km in diameter. Radiometric dating revealed that this massive ring of displaced rock was 66 million years old. The crater made by the meteorite responsible for showering the earth with debris at the end of the Cretaceous had been found. Based on the crater's size, it has been calculated that the meteorite that made it must have been 10 kilometers in diameter, larger than Mount Everest.



The pattern formed by the limestone sinkholes called cenotes formed part of a ring. Geological imaging revealed a huge impact crater! Images by NASA, in the public domain.

Learning objective 12.5 – Evaluate competing hypotheses for the cause of the end-Cretaceous extinction.

There have been many ideas put forward to try to explain the cause of the End-Cretaceous extinction. Some of these ideas are more plausible than others. It has been suggested that dinosaurs went extinct because small mammals began eating all of the dinosaurs' eggs. Not only does this idea not take into consideration the fact that mammals and dinosaurs evolved at roughly the same time (and, therefore, dinosaurs had been successfully coexisting with small mammals for over 160 million years and laying eggs all the while), but it also fails to explain why so many other kinds of organisms died out at the same time.

It is commonly and incorrectly thought that the Cretaceous period was immediately followed by an ice age and that widespread glaciations and freezing temperatures were responsible for the dinosaurs' demise. While average global temperatures did fall after the Cretaceous, this temperature fall was gradual, and it was millions of years before a true ice age resulted.

Some hypotheses are very unlikely, and would be almost impossible to test scientifically. Sometimes you may see reports in the media about dinosaurs generating too much methane gas from their digestive systems, thereby causing climate change – these kinds of news items usually are based on mathematical estimates that make a lot of assumptions about dinosaur physiology and ecology. Other ideas, like that the dinosaur's demise was caused by a nearby supernova or a viral outbreak, leave little evidence in the fossil record. And remember, whatever caused the extinction needed to kill not just a few species of dinosaurs, but all of the dinosaurs, and all of the other disparate organisms that went extinct at the same time.

A mass volcanic outgassing of carbon dioxide and ash plumes has also been suggested as a possible cause of the extinction. This scenario could potentially have affected the global climate enough to have caused the extinction of many kinds of organisms, and there is a record of high volcanic activity in the Deccan Traps of India at the end of the Cretaceous.

The current prevailing theory for the cause of the End-Cretaceous extinction is more cosmic. Without a doubt, a very large meteorite struck the Earth in the Yucatan peninsula at about the same time we see a mass extinction in the fossil record. But how could a single meteorite impact, even a massive one, have killed off so many kinds of animal that lived all across the globe? The theory goes like this: The initial impact caused huge tsunamis and sent a great cloud of super-heated rock and dust high into the atmosphere. The rocks and larger pieces of debris quickly fell to earth and started wildfires. Smaller pieces of debris next began to fall and, as they fell, were heated by air friction. This rain of hot dust raised global temperatures for hours after the impact and cooked alive animals that were too large to seek shelter. Small animals that could shelter underground, underwater, or perhaps in caves or large tree trunks, may have been able to survive this initial heat blast.

Finally, much debris would have remained in the atmosphere for perhaps months or even years. The residual haze would have reduced sunlight, killing many plants and other photosynthetic organisms, with rippling effects up the food chain. Some scientists estimate that photosynthesis may have stopped for at least a decade – try to imagine the world surviving without any plants for years at a time! The reduced sunlight may also have brought on a sudden drop in global temperatures. Being large active animals with high energy needs and positioned at the top of prehistoric food chains, dinosaurs were highly susceptible to this series of catastrophes. Smaller, omnivorous terrestrial animals, like mammals, lizards, turtles, or birds, may have been able to survive as scavengers feeding on the carcasses of dead dinosaurs, fungi, roots, and decaying plant matter. , while smaller animals with lower metabolisms were best able to wait the disaster out.

The meteorite impact scenario is support by good geological evidence (the impact crater of the right age, and the presence of iridium, tektites, and shocked quartz), and seems to be a reasonable explanation of the patterns of extinctions observed in the fossil record. Many animals would have died in the moments and hours after the Chicxulub impactor struck the earth, either as a result of the shockwaves,

The Age of Dinosaurs has come to an end: in the years following the Chicxulub impact, photosynthesis is reduced, and large herbivores have starved. With no more carcasses to scavenge, a lone *Tyrannosaurus* dies at the edge of a lakeshore. Its body will be scavenged by members of the two remaining archosaur lineages: birds and crocodilians. By Jan Sovak.

tsunamis, forest fires, or heating of the atmosphere. In the months and years that followed, food chains collapsed as photosynthesis halted. Animals like turtles, champsosaurs, crocodilians, and small mammals and birds could find shelter immediately after the impact, and were not at the top of the food chain, and therefore were more likely to survive. Unfortunately, most dinosaurs were neither of these things – they were the dominant terrestrial herbivores and carnivores, and most (but not all) were too large to find shelter during the impact. Today the dinosaurs are represented only by their descendents, the birds.

Learning objective 12.8 – Assess the likelihood that dinosaurs could be brought back from extinction.

Will human eyes ever see a living breathing *Tyrannosaurus* or *Triceratops*? For those of us living here in the twenty first century, it does not seem likely.

You may be familiar with a certain Hollywood franchise that popularized the science fiction premise of cloning dinosaurs from discoveries of their DNA. Unfortunately, DNA is a delicate substance that quickly breaks down over time. It is extremely unlikely that a complete or nearly-complete DNA strand could ever be preserved (even inside the body of a mosquito stuck in amber) for 66 million years or more. Some recent discoveries of blood vessels in the Late Cretaceous dinosaurs *Tyrannosaurus* and *Brachylophosaurus* suggest that soft tissues and potentially even proteins may be able to survive this long. But such material is still a long ways from what would be needed to even consider cloning a dinosaur. Even if dinosaur DNA was found intact, cloning is a difficult process. Scientists have not yet been able to successfully clone even recently extinct animals and have the clone survive for more than a few minutes.

It might be possible to find more recent dinosaur DNA. Remember that birds are one branch of the dinosaur family tree. As such, the DNA of birds contains many of the DNA sequences of their ancestors (but with many of these genes switched off). It has been proposed that a dinosaur could be resurrected by hatching a bird with its advanced DNA sequences turned off and its ancient ancestral sequences turned back on. In this way, perhaps a bird would develop with a long bony tail, teeth, and clawed fingers. But, for the moment, performing such genetic manipulations is well beyond our understanding and technology.

Supplementary Materials.

Science@NASA – What exploded over Russia? [Video]

Recent asteroid impacts visualization – asteroid impacts are surprisingly common!

Laelaps – Dinosaurs had the worst luck. [Blog post]

Laelaps – Planting the Cenozoic garden. [Blog post]

Smithsonian – The top 10 weirdest dinosaur extinction ideas. [Blog post]

Io9 – How to survive a mass extinction. [Blog post]

Earth Unplugged - Woolly Mammoth: Back from extinction. [Video]

TED Talks – Building a dinosaur from a chicken. [video]

This one is just for fun: What would have happened if the dinosaurs didn't go extinct? You might be surprised to learn that palaeontologists have given this thought experiment a try a couple of times! Tetrapod Zoology - Dinosauroids Revisited, Revisited.