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Mass extinctions

In the 1830s, geologists realized that there were major differences between the trilobite-coral-crinoid-brachiopod-dominated fossil assemblages early in geologic history, and the mollusk-echinoid-dominated faunas that populate the sea floor today. They named the Paleozoic, Mesozoic, and Cenozoic eras for these major changes in marine fossils. In recent years, paleontologists have come to realize that the boundaries between the Paleozoic and Mesozoic eras (or the Permian and Triassic periods) and the Mesozoic and Cenozoic eras (or the Cretaceous and Tertiary periods) are marked by mass extinctions, when more than 30% of the genera of animals become extinct in less than a million years. These mass extinctions are more than just the accumulation of extinction at the normal "background" rate, because they often wipe out long-lived groups of animals that were successful during normal times and resisted extinction over long time scales but did not survive the catastrophic events of a mass extinction.

There are five recognized intervals (the "Big Five") where the extinction rate was well above the background level. These intervals have become accepted as the major mass extinction events in life's history. In recent years, much attention and research has focused on these events, and many claims have been made for their causes. However, as these ideas have undergone scientific testing, some of the more outrageous claims have been discredited.

Permian-Triassic extinction. The biggest mass extinction of all occurred at the end of the Paleozoic Era, 251 million years ago (Ma). This was "the mother of all mass extinctions" when possibly 95% of all marine species on the sea floor vanished and many land animals died out as well. The victims included most of the groups that dominated the Paleozoic Era, from the last surviving trilobites, graptolites, tabulate and rugose corals, and blastoid echinoderms, to the majority of the groups that were thriving in the Permian, including the fusulinid foraminiferans, the common groups of brachiopods, crinoids, and bryozoans, and all but two species of ammonoids. The clams and snails, on the other hand, suffered much less extinction, and during the ensuing Triassic Period they came to dominate the sea floor (as they still do today). On land, many groups of "protomammals," archaic amphibians, and land plants vanished. Recent detailed studies showed that the Permian-Triassic extinction was fairly abrupt (less than 10,000 years in duration).

In past years, scientists blamed the Permian-Triassic extinction on the loss of shallow-marine habitat on the sea floor when the supercontinent of Pangaea formed (but this occurred gradually, starting at the beginning of the Permian), or on the global cooling caused by south polar glaciation (but this also occurred early in the Permian). Recently, several important historical phenomena have emerged. The oceanographic evidence from carbon isotopes suggest that oxygen levels were severely depleted, and that huge amounts of carbon were released into the world's oceans; this would have led to carbon dioxide–oversaturated waters (hypercapnia) that may have poisoned the sea floor, and low oxygen levels on land that made it hard for most land animals to breathe. In addition, other evidence points to a runaway greenhouse warming and rapidly fluctuating climates at the end of the Permian, which may have raised global temperatures beyond the tolerance of many organisms. The end of the Permian was also marked by one of the biggest volcanic eruptions in Earth history, the Siberian basalts, which released over 1.5×10^6 km^3 (3.6×10^5 mi^3) of lava, and may have also released huge quantities of carbon dioxide and sulfur into the atmosphere that could have triggered the hypercapnia and global warming. Some scientists have tried to blame the Permian extinctions on some kind of extraterrestrial impact, but the evidence for impact has always been questionable, and does not explain the geochemical signals of carbon, oxygen, and sulfur found in the oceans and on land.

Cretaceous-Tertiary (KT) event. The second biggest extinction event, when perhaps 70% of species on Earth vanished, occurred 65 Ma. This is the most well studied of all mass extinctions, because it marked the end of the dinosaurs (except for their bird descendants), as well as the coiled ammonites (like the chambered nautilus) that ruled the seas for over 300 million years and survived many previous mass extinctions. This period also marked major extinctions of the plankton, the clams and snails, and all of the marine reptiles that had once ruled the seas. On land, the nonavian dinosaurs and some land plants died out, but most other land animals and plants were unaffected.

For decades, scientists speculated about the extinction of the dinosaurs and suggested various ideas about their demise. They thought that climates might have become too hot or too cold, or that mammals ate their eggs (but mammals and dinosaurs had coexisted for over 150 million years), or that dinosaurs could not eat the new flowering plants (but these plants appeared at the beginning of the Cretaceous), or disease. But all of these explanations fail because they focus exclusively on the dinosaurs, when the KT event was a mass extinction that affected everything from the bottom of the food chain (plankton, land plants) to organisms such as clams and ammonites, to the top land animals like the dinosaurs and the top predators of the sea, the marine reptiles.

In 1980, the KT extinction debate was galvanized when evidence of a huge impact of a 10-km-diameter (6-mi) asteroid was discovered. This led to more than 20 years of fierce debate as the evidence was evaluated and much of it rejected. Almost 25 years later, it is now clear that there was a major impact that hit the northern Yucatan Peninsula at a site known as Chicxulub. The end of the Cretaceous was also marked by huge volcanic eruptions, the Deccan lavas, which covered over 10,000 km^2 (3860 mi^2) of western Indian and Pakistan with as much as 2400 m (7875 ft) of lava flows, and released huge quantities of mantle-derived gases into the atmosphere. The Cretaceous ended with a global drop in sea level, or regression, that affected both land and marine communities.

Although the impact advocates have dominated the discussion and the popular views, the data are much more complex than has been portrayed. Many of the organisms (especially the rudistid and inoceramid clams, most of the plankton, the marine reptiles, and possibly the dinosaurs and ammonites) were dying out gradually in the latest Cretaceous, and may not have even been alive during the Chicxulub impact. This evidence cannot be explained by a sudden impact but only by a gradual cause, such as a regression or global climatic change triggered by volcanic gases. More importantly, many marine organisms, such as the majority of clams, snails, fish, and echinoids, some plankton, and many land organisms (such as the crocodilians and turtles, the amphibians, and most of the mammals) lived right through the KT extinctions with no apparent ill effects. If the KT impact were so severe that it caused a global "nuclear winter" of cold and darkness, and huge clouds of acid rain (as some have suggested), none of these organisms would still be alive on Earth. Amphibians, in particular, are sensitive to small changes in the acidity of their ponds and streams, so the "acid rain" hypothesis is discredited. Currently, most scientists agree that some sort of gradual cause such as regression and/or the Deccan eruptions might explain the demise of most Cretaceous organisms, and the Chicxulub impact was only a minor coup de grâce that may have finished off the last of the nonavian dinosaurs or ammonites.

Other extinctions. The remaining "Big Five" extinctions were much less impressive than the two that began and ended the Mesozoic Era. The third biggest was the Late Devonian extinction (about 365 Ma), when much of the tropical coral and sponge reef community was decimated along with many other marine invertebrates and archaic fish groups that had flourished in the earlier Devonian. Although impacts have been blamed for the event as well, current evidence from marine isotopes favors a severe global cooling. The fourth biggest is the Late Ordovician extinction (about 445 Ma), when about 60% of the marine genera died out. This, too, has been blamed on a short-term global cooling event, with no evidence for impact. The fifth event, the Triassic-Jurassic extinction (about 208 Ma), affected some marine organisms (like the ammonoids, conodonts, snails, brachiopods and crinoids), and many archaic land reptiles, amphibians, and protomammals. Although this event had also been blamed on impact the evidence has been discredited, and currently the huge eruptions caused by the opening of the North Atlantic are considered a more likely cause.

Mass extinctions are major events that completely rearrange the ecology of life on Earth. Over the past 20 years they have been intensively studied, and some scientists have gone so far as to blame them all on extraterrestrial impacts. However, more recent analyses have shown that only one event (the KT extinction) is clearly associated with impact, and even in this case it is not the major cause of the mass extinction. Instead, massive volcanic eruptions and/or major climatic changes played a more important role.

For background information *see* CENOZOIC; CRETACEOUS; DATING METHODS; EXTINCTION (BIOLOGY); FOSSIL; GEOLOGIC TIME SCALE; MESOZOIC; PALEONTOLOGY; PALEOZOIC; PERMIAN; STRATIGRAPHY; TERTIARY; TRIASSIC in the McGraw-Hill Encyclopedia of Science & Technology. Donald R. Prothero

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Mass spectrometry (carbohydrate analysis)

The functional significance of carbohydrates in biological systems is quite diverse. For example, carbohydrates cover the surface of some bacteria, such as *Haemophilus influenzae*. Carbohydrates in the outer lipid coat may aid in disguising these bacteria by mimicking substances naturally present in humans. They are also key components of cartilage, where they form polymeric chains of negatively charged monosaccharides. The negative charges provide electrostatic repulsion when the cartilage undergoes compression. Carbohydrates also are present on the surface of many proteins. Their presence is sometimes necessary to assist in protein folding or receptor binding. The protein that covers the surface