MASS EXTINCTIONS

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The vast majority of species meet their end in this way. Most dinosaurs did not die out in the asteroid strike - after 165 million years of evolution, hundreds or thousands of species had already been and gone. Sometimes many species disappear together in a short time. At the end of the ice ages 11,000 years ago, for example, mammoths, woolly rhinos, cave bears and other large mammals adapted to cold conditions died out across Europe and North America.

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WHAT IS A MASS EXTINCTION?

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There have been many such “mass extinction events” through the history of life. Occasionally extinction events are global in scale, with many species of all ecological types - plants and animals, marine and terrestrial - dying out relatively short time all over the world. This is mass extinction.

There is no exact definition of a mass extinction. The threshold of 90 per cent of species is about the norm, but this is only the upper end of a spectrum of extinction events. There is no set timescale either: some extinctions happen relatively quickly, like the K-T event, others take several million years, as in the late Ordovician. It all depends on the cause (see p.v).

Given how important mass extinctions are to understanding the history of life, it may seem surprising that no one was much interested in the idea until the 1970s. Of course, the great Victorian palaeontologists such as Richard Owen and Thomas Huxley were aware that dinosaurs and other ancient creatures were extinct, but they did not see any role for sudden, dramatic events.

Following Charles Darwin, they argued that extinction was a normal process: species originated at some point by splitting from existing species, and at some point they died out.

This mindset can be traced back to Charles Lyell, who in the 1830s argued that the history of life was the record of a slow, continuous change. This holds that “the present is the key to the past” - all geological phenomena can be explained by processes we see today, extrapolated over enormous periods of time.

In fact, until quite recently, geologists were conditioned against seeing any evidence of major crises. It all began to change in the 1960s, a time of ferment and revolution for geologists when ideas of an immobile Earth were rejected in favour of the dynamic reality of plate tectonics. That decade also saw the birth of impact geology.

Shoemaker also investigated a large circular depression called Nördlinger Ries in Bavaria, Germany. There he found coesite and stishovite, along with suevite, a type of rock composed of partially melted material. The depression is now considered to be an impact crater some 3.5 million years old.

Around the same time, palaeontologist Norman Newell of Columbia University in New York began building the case that the fossil record contained evidence of large-scale extinctions. With his work the concept of mass extinctions began to gain currency.

Even so, when Luis Alvarez of the University of California, Berkeley, and his colleagues proposed in 1980 that the dinosaurs had been killed off by an asteroid impact the world was still not ready to believe it. Opposition to the idea was substantial, and it took another decade to convince the world that this catastrophic event really did happen.
THE DEATH OF THE DINOSAURS

The extinction of the dinosaurs 65 million years ago, at the Cretaceous-Tertiary (KT) boundary is the most recent of the major mass extinctions and the one most amenable to study. Rocks from before, during and after the event are more abundant, detailed and datable than those for older events. So its cause was just waiting to be resolved.

Up to the 1970s the best evidence suggested that the dinosaurs – along with plesiosaurs, mosasaurs, plesiosaurs, ammonites and many other groups - declined slowly over some 10 million years as a result of cooling climates. Then came the bombshell. In 1980 Luis Alvarez, who had already won a Nobel prize in physics, his geologist son Walter and other colleagues published an astounding paper in Science (vol 206, p 1295).

The team had set out to use the element iridium as a geological timekeeper, but ended up with remarkably different findings. Iridium is very rare on Earth’s surface, and the rate, so iridium can be used to mark the passage of meteorites. These hit the Earth at a low but steady minute quantities that are present arrived on geological timekeeper, but ended up with remarkably an astounding paper in

The paper caused an outcry, mainly because it drew to their impact theory. In 1985 with a sample of the rock that led structure. Blue and violet represent low-density

One mass extinction truly dwarfs all the others. Whereas earlier and later events each seem to have extinguished around 50 per cent of species, the end-Permain extinction was associated with a loss of 80 to 90 per cent of species in the sea and on land. Several major groups disappeared, including trilobites and giant sea scorpions called eurypterids. The vast scale of the extinction is shown by the fact that two major structural ecosystems disappeared – reefs and forests. Nothing like that has happened in any of the other mass extinctions.

Reefs first appeared in the Cambrian, and by the Permian had become a major ecosystem hosting substantial biodiversity, as they do today. With the loss of the dominant reef builders, the rugose and tabulate corals, the Earth was cleared entirely of reefs. It took 15 million years for new groups to evolve and build reefs once more.

Forests likewise virtually disappeared. There is a famous “coal gap” in the early and middle Triassic when forests anywhere, even in the tropics, played by massive volcanic eruptions: 252 million years ago, massive volcanoes erupted in Siberia and they continued to belch Earth viscous basalt lava and massive clouds of gases for 500,000 years. These were not conventional cone-shaped volcanoes but great rifts in the Earth’s crust. The gas from the eruptions now forms a vast formation known as the Siberian Traps.

Sulphur dioxide caused flash freezing for a short time by blocking the sun, but this gas dissipated rapidly. More long-lasting was the greenhouse gas carbon dioxide, which caused global warming and ocean stagnation. Repeat eruptions kept pumping carbon dioxide into the atmosphere, perhaps overwhelming the normal feedback in which plants mop up the excess through photosynthesis. The warming probably also released frozen masses of methane, an even more potent greenhouse gas, from the deep ocean.

The earliest Triassic rocks contain evidence of repeat cycles of ocean stagnation: their black colour and rich supply of pyrite indicate oxygen-poor conditions. These dark, sulphurous rocks contain very few fossils. In contrast to the abundant and diverse fossils in the limestone just below the extinction level. On land, the volcanic gases mixed with water to produce acid rain. Trees died and were swept away together with the soils they depended, denuding the landscape. Land animals perished as their food supplies and habitats disappeared.

The slaughter of life in the sea and on land left a devastated Earth. Pulses of fresh warming continued for 5 million years, delaying the recovery of life. Some “disaster taxa” such as conifers, a pig-sized herbivore, gained a foothold here and there, but it took 15 million years for complex ecosystems to recover. Even then, they took 15 million years for complex ecosystems to recover.
Mass extinctions are devastating, and yet life recovers. The rate of recovery depends on many factors, but the most important is the scale of the extinction. After mass extinctions, life recovers within a few million years, though the end-Permian event was different. It was twice as large as most of the others, and so it is no surprise that the time to recovery was greatest. Recovery also depends on which plants and animals survive. If the mass extinction hit all groups more or less equally, as most seem to, then there is a good chance that one or two species from each major group will survive. These act as an ecological framework, occupying most of the broad niches, and so the basic ecosystem structure survives. New species evolve to plug the gaps and the recovered ecosystem may be quite comparable to the one that existed before the disaster.

A more selective event, on the other hand, might leave broad sectors of aspace vacant. A variety of the survivors then jockey for position, evolving to fill the vacant niche. After the KT event it was by no means a foregone conclusion that mammals would take over. Indeed, in North America and Europe, giant flightless birds became the dominant carnivores, some of them famously preying upon ancestral (admittedly terrier-sized) horses. In South America, giant birds and crocodilians vied with each other to become the top carnivores, and mammals only replaced them some 30 million years later. Mass extinctions, then, have a creative side. Marginal groups sometimes get a chance to expand and become dominant. Most famously, mammals benefited from the demise of the dinosaurs.

In fact, mammals first evolved in the late Triassic, at the same time to recovery was greatest. After the KT event it was by no means a foregone conclusion that mammals would take over. Indeed, in North America and Europe, giant flightless birds became the dominant carnivores, some of them famously preying upon ancestral (admittedly terrier-sized) horses. In South America, giant birds and crocodilians vied with each other to become the top carnivores, and mammals only replaced them some 30 million years later. Mass extinctions, then, have a creative side. Marginal groups sometimes get a chance to expand and become dominant. Most famously, mammals benefited from the demise of the dinosaurs.

The end-Permian mass extinction was even more creative, with a yawning post-extinction aspace providing opportunities for the survivors. In the sea, molluscs (bivalves and gastropods) took over roles previously occupied by brachiopods. Scleractinian corals took over roles previously occupied by bryozoans and stony corals. Light-scaled fishes moved into roles previously occupied by more primitive ones. On land, the key beneficiaries of the extinction might have been the dinosaurs, whose earliest ancestors emerged within 5 million years of the crisis.

Impacts, Volcanoes, What Else?

The causes of the two of the largest mass extinctions are now reasonably well understood (see pages iv and v). But what of the others? In some cases it is difficult to say. The fossil record clearly shows a huge loss of life but not what caused it. Over the years, a number of possibilities have been put forward, but the cause of two of the big five - the end-Neoproterozoic and end-Triassic - remains uncertain.

Continent Movements. During the Permian and Triassic, all continents were fused into a supercontinent, Pangaea. At one time, the end-Permian mass extinction was linked to this, based on the suggestion that fusion of continents removes intercontinental seas, each with its own unique fauna, and allows land animals and plants to mix. It now seems, however, that such movements are too slow to lead to massive species loss.

Ice Ages. The late Ordovician mass extinction has been explained as a consequence of a massive ice age, particularly the growth of a huge southern ice cap. As the ice spread, species migrated towards the equator and warm-adapted species may have disappeared. Sea levels fell dramatically, reducing many inland seas and causing widespread extinction.

Anoxia. The late Devonian extinction has been linked to a lack of oxygen in the ocean, possibly caused by sudden temperature changes or massive increases in the supply of sediment from the land caused by the rise of terrestrial plants.

Parts of the post-dinosaur world were briefly ruled by giant birds like Castorini (above), before mammals took over.
THE NEXT MASS EXTINCTION?

It is often said that we are living through the sixth mass extinction, this one induced by human activity. The point is well made: the present biodiversity crisis appears to be comparable in scale to many of the biotic crises of the past.

There can be no doubt that many species have gone extinct on our watch. We know, for example, that the last great auk was killed by collectors in 1844, the dodo was last seen in 1662 and the last passenger pigeon died in a zoo in 1914. Hunters shot the last quagga, a zebra-like wild horse, in the 1870s and the last thylacine – or Tasmanian tiger – died in captivity in 1936. These examples, however, tell us little about the scale of the crisis. For that we have to aggregate known historical extinctions. Unfortunately the records are not good, but we do know that 130 species of bird were driven to extinction by hunting between 1500 and 2000. This gives us a starting point.

There are currently some 10,000 bird species, so these extinctions represent a loss of 1.3 per cent of species in 500 years, or three species every year. This is a very rough estimate but it suggests claims of a sixth mass extinction are not exaggerated. It could of course be objected that this rate of loss cannot proceed inexorably. The optimist might argue, for example, that most of the species so far driven to extinction were already rare or vulnerable, and that they were hunted without mercy in less enlightened times. There is surely some truth in these assertions: it is unlikely that globally distributed species such as sparrows, rats or mice would be so easy to exterminate as the dodo. Further, no nation would allow hunters to slaughter animals as systematically as was done by Victorian-age hunting parties.

However, despite tighter controls on hunting and growing conservation efforts, pressure on natural habitats has never been more extreme. Whiol it is frustratingly hard to put precise figures on current rates of species loss, uncertainties should not be seen as a reason for complacency. The fossil record shows how devastating mass extinctions are and that, although life does recover, it takes millions of years to do so. The study of mass extinctions, and comparisons with the modern world, show that we are almost certainly responsible for another mass extinction, and the living world could soon be a much-diminished place.

RECOMMENDED READING
Mass Extinctions and their Aftermath by Tony Hallam and Paul Wignall (Oxford University Press)
When Life Nearly Died: The greatest mass extinction of all time by Michael J. Benton (Thomas G. Hudson)
T. rex and the Crater of Doom by Walter Alvarez (Princeton University Press)
Vanishing Life: The mystery of mass extinctions by Jeff Hecht (Prentice Hall & BDI)

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