The Sixth Extinction by Elizabeth Kolbert

By Philip Guelpa
31 May 2014

In recent weeks, two reports have emphasized the grave dangers posed to humanity by accelerating climate change (see "US climate report points to human activity as primary cause of climate change" and "Study warns of 'unstoppable' West Antarctic ice shelf melting"). As a growing body of research over recent decades has made clear, human activities are responsible for alterations in Earth's environment that will, if not addressed, lead to devastating consequences for humans and all life on this planet.

The Sixth Extinction (2014), authored by Elizabeth Kolbert, reviews possible consequences of large-scale climate change. Using geological and paleontological evidence, Kolbert describes how, at least five times in the past, severe disruptions in Earth's climate have caused the extinctions of large portions of the life forms extant at the time. The most well known is the extinction of the dinosaurs, along with many other species, at the end of the Cretaceous Period, approximately 66 million years ago (mya), almost certainly caused by the collision of a large asteroid with our planet, resulting in the equivalent of "nuclear winter." Indeed, the concept of nuclear winter was developed by Carl Sagan and others once the cause of the dinosaur extinction was understood.

However, the end-Cretaceous extinction was not the most catastrophic of these events. That distinction falls to the devastation that occurred at the end of the Permian Period, 252 mya, known as "The Great Dying." Approximately 90% of marine species and 70% of terrestrial species disappeared in what, geologically speaking, was the blink of an eye. So dramatic was the change in life forms that this event defines the boundary between the Paleozoic era (541 to 252 mya) and Mesozoic era (252 to 66 mya).

One might say that the course of life on Earth experienced a fundamental "reset" at the end of the Cretaceous and, indeed, at each of the other mass extinctions as well. The world that we know, dominated among the larger animals by birds and mammals, including humans, would not exist had it not been for the devastation caused by the impact of the Chicxulub asteroid that extinguished the dinosaurs (see "Study finds mammals diversified only after the extinction of dinosaurs").

The specific causes of each extinction event appear to differ. As indicated, the end-Cretaceous extinction was caused by the collision of Earth with another celestial object. The extinction at the end of the Ordovician (485 to 443 mya) appears to have been caused by extensive glaciation. The Great Dying is thought to have been the result of massive volcanic eruptions in what is now Siberia, resulting in the emission of huge amounts of gases (including methane from the burning of organic materials) that triggered a runaway "greenhouse effect."

The fundamental lesson to be drawn from an understanding of the markedly erratic course of life on Earth is that the climate, which sets the parameters within which all forms of life exist, is fragile. While physical and biological systems have a certain resiliency, once pushed beyond a critical point dramatic changes can occur. Included in these changes is the threat to the continued existence of human civilization.

Much of Kolbert's book contains accounts of trips she has taken to visit researchers, in the field and the laboratory, who are examining past extinctions as well as those occurring at the present time. In one chapter, "Dropping Acid," she discusses ocean acidification, an ongoing process caused by human activities. Kolbert describes research involving "natural experiments," created by carbon dioxide escaping from volcanic vents in the Mediterranean. The gradient of increasing acidity approaching the vents (dissolved carbon dioxide forms carbonic acid) is mirrored by a decrease in the diversity of marine life. In the areas closest to the vents almost nothing lives. This gradient likely foreshadows what will take place as increasing levels of atmospheric carbon dioxide raise the acidity of the oceans.

Ocean acidification played a major role in at least two of the great mass extinctions.

In other chapters, Kolbert discusses the consequences of additional human-induced processes such as global warming, which is occurring at 10 times the rate at the end of the last glaciation; destruction of habitat, due to uncontrolled development; and the rapid spread of "invasive species," promoted by human travel and international commerce. All of the trends point to the accelerating loss of plant and animal species. Less diverse ecosystems are more unstable, setting the stage for "positive feedback loops" in which each extinction places greater strains on delicate ecological balances, thus making the likelihood of more extinctions even greater, as well as promoting climate instability (e.g., loss of forests destabilizing global rain patterns).

The achievement of our current understanding of the evolution and extinction of life on Earth has not been a straight-line development of the gradual accumulation of knowledge. Rather, major competing theoretical frameworks were formulated to explain the growing and seemingly contradictory body of evidence derived from field research. Proponents of each of these viewpoints, which can be broadly grouped into the categories uniformitarianism and catastrophism, sought to make sense of the data by developing explanations that would fit the pieces of the fragmentary puzzle left in the geologic strata and fossilized remains of plants and animals into a coherent whole.

As it turns out, despite the frequently acrimonious contention between advocates of each view, who regarded these differing interpretations as completely incompatible, we now understand that both are correct.

The catastrophists, originating with the French anatomist and paleontologist Georges Cuvier, recognized that the fossil record contained irrefutable evidence of many extinct species and that these were found in geologic strata indicating the existence of a succession of past conditions on Earth very different from those of modern times. Furthermore, the seemingly abrupt discontinuities between major stratigraphic units, as for example between the Mesozoic (252 to 66 mya), which was dominated by dinosaurs, and the Cenozoic (66 mya to the present), the age of mammals and birds, suggested that the transitions between these major periods were catastrophic, involving immense upheavals that led to the rapid extinction of large numbers of species followed by the appearance of radically new ones.

The intellectual climate of the late eighteenth and early nineteenth centuries, during which catastrophism was born, was strongly influenced by the Enlightenment and the French Revolution, as well as developing industry and transportation. The French Revolution demonstrated that

society was not static, but rather could undergo rapid and radical change, causing the abrupt replacement of an existing social order by a vastly different one. If this was true of social relations, could it not be equally true of the natural world? At the same time, the industrial revolution resulted in major excavations into the planet's surface—for example, in the digging of canals and large-scale mining operations, exposing geologic deposits to a much greater degree than ever before and, thereby, revealing complex geologic stratigraphy and the immense diversity of the paleontological record.

This flood of new data coupled with a general revolutionary outlook seemed to provide solid support for the catastrophic view of the development of life on Earth. It proposed a plausible framework for understanding the apparent patterns being observed in the fossil record. There was a major weakness in catastrophism, however. It did not explain how new forms of life appeared to replace the old ones. Indeed, some catastrophists interpreted what they saw as evidence of a succession of "creations," demonstrating repeated divine intervention, which produced a series of new worlds "de nouveau."

Uniformitarianism, championed by Charles Lyell and Charles Darwin, took a diametrically opposed view. This school proposed that the observed patterns of both geologic and biologic phenomena could be explained by reference to processes that could be observed in the modern world—erosion, sedimentation, glaciation, and, among living forms, natural selection—operating slowly over vast stretches of time. This theory too was fueled by the vast amounts of data being generated due to exploration and industrial development. The Darwin/Wallace theory of evolution would not have been possible without the mass of comparative data accumulated from different parts of the world as a byproduct of colonial expansion.

The uniformitarian view proved very powerful in explaining many of the patterns being observed in current and past life. Indeed, it became dominant for many decades. However, like catastrophism, it too had a fundamental flaw. Uniformitarianism could not explain the major temporal discontinuities observed in the fossil record as well as puzzling biogeographic distributions (similar species occurring in widely separated locations).

Advocates of the uniformitarian view conceived of evolution as a slow process, with speciation somewhat (the evolution of new species) outpacing extinction. They tended to ignore or downplay human-induced extinctions, which were known to be taking place during the nineteenth century. Uniformitarians dismissed the idea that abrupt changes exhibited in the fossil record were the reflection of mass extinctions. Instead, they were forced to postulate vast gaps in the geologic and paleontologic record. The remains from tens of millions of years of Earth's history were simply "missing," for no apparent reason. These lacunae were hypothesized in order to account for the huge amounts of time that would have been needed for "slow" evolution to produce the radical differences between, for example, the dinosaurs of the Mesozoic and the mammals of the Cenozoic.

Biogeographic anomalies, such as similarities between fossil species in North and South America, on the one hand, and those in Europe and Africa, on the other, continents separated by the wide Atlantic Ocean, and thus impossible to cross by most terrestrial species, could not be accounted for. Even though the theory of continental drift was proposed in the late nineteenth century, it was rejected and ridiculed by adherents of uniformitarianism. They proposed instead the existence of "land bridges," which had mysteriously appeared and then disappeared, but for which there was no physical evidence.

Over time, however, evidence began to be uncovered that first demonstrated the reality of continental drift and then the catastrophic asteroid impact that exterminated the dinosaurs. Kolbert describes at some length the struggle of Walter and Luis Alvarez to overcome the fierce opposition to their theory about the cause of end-Cretaceous extinction. Gradually, based on a growing mountain of data, the extraterrestrial cause of this extinction was adopted by the majority of the scientific community.

The acceptance of the reality of this and other mass extinctions leads to a richer and more complex understanding of biological evolution. The rate of evolution is not constant. There are long periods during which it progresses at a relatively slow pace, as the uniformitarians would have it. At other times, for various reasons, the environment suffers accelerated change. This causes the rates of both extinction and, subsequently, speciation to speed up. The relatively "empty" landscape following a mass extinction offers the survivors a multiplicity of opportunities to expand and diversify, as the mammals did after the extinction of the dinosaurs.

Natural selection remains operative whether the evolution of new species is occurring rapidly or slowly. It is not, however, the controlling factor during periods of mass extinction, when changes in the environment are occurring so rapidly that it is impossible for adaptation to occur.

When confronted with the overwhelming catastrophe caused by the massive asteroid impact 66 mya, nearly all larger animals (everything above the size of a house cat), along with many smaller organisms, were wiped out within the span of less than a generation. Descent with modification, the hallmark mechanism of Darwinian evolution, simply could not operate for a great number of species. One might view the event as selection in the extreme, not favoring some individual members of a species over others of that same species, but rather as a mass culling of all species with large body sizes or other suddenly unfavorable characteristics due to overwhelmingly extreme environmental conditions.

Fundamentally, the pace of evolution of any given group of organisms depends on the relative balance between the rate of change of the environment, both physical and biological, and the availability of genetic "resources" within the gene pool of the species to provide a basis for adaptation to this changing environment. If adequate genetic diversity exists so that sufficient numbers of individuals can survive and reproduce successfully to sustain a viable population, then there is a fighting chance for adaptation by the species to the new environment. If, on the other hand, the gene pool does not contain the kinds of characteristics that would allow survival under the changed circumstances, or if the change occurs so rapidly that a large portion of the population dies off before the beneficial characteristics that exist in the gene pool can gain a foothold, then extinction is the likely outcome.

It is evident, therefore, that catastrophism and uniformitarianism are not mutually exclusive. They are, in fact, simply the opposite ends of a spectrum. Localized catastrophes—the introduction of a previously unknown disease, for example—may impact one portion of a species' range, possibly creating conditions under which ecological opportunities arise for a new species to evolve. The dialectic of evolution is always operative, only differing with regard to rate and scale.

The kinds of catastrophic changes in the Earth's environment that have repeatedly devastated large segments of plant and animal life could well be repeated in the near future, but this time due to uncontrolled human activity. The fact that Earth's climate has at times been very different from that in the recent past means that we cannot take for granted the continuation of the relatively hospitable natural environment to which we are accustomed. Extreme conditions that have occurred in the past due to natural processes could be replicated, this time by human activities, creating an environment in which it would be difficult or impossible for humans, let alone most other forms of life, to survive.

This dire scenario is by no means inevitable, however. The scientific and technological means exist to greatly slow and eventually even reverse the human-induced causes of climate change. To implement the necessary

measures, rational, scientifically planned actions would have to be taken. The necessary steps are possible only if control of the economy is taken out of the hands of private capitalists, whose actions are driven by the need to maximize immediate gain for a small elite regardless of long-term consequences. Without exaggeration, this is a matter of life and death for the whole of humanity.