Mass Extinctions Select Different Victims

Every now and then during earth history the rate of extinction has soared, producing mass extinctions; the victims are not just more of the same but include different types of species

Mass extinctions have been much in the news of late, not least because of the suggestion that the extinction event that included the demise of the dinosaurs might have been triggered by catastrophic collision between the earth and an asteroid. Even more contentious is the proposal that major extinctions recur every 26 million years or so, perhaps as a result of periodic showers of comets.

While these various claims still remain a matter of vigorous debate, there has emerged yet another feature of mass extinctions that, although not as headline-catching as rocks falling out of the sky, is at least as important in the understanding of the patterns in the history of life on Earth. This has to do with the types of organisms that are vulnerable during major extinction events as compared with other, less dramatic periods of extinction.

Major extinction events are separated by periods of lower extinction rates, typically referred to as background extinction. And ever since this pattern of alternating background and major extinction was recognized, it has been generally assumed that the only difference between the two regimes was quantitative. In other words, the same types of species succumbed to mass extinctions as to background extinction, but a lot more of them.

This assumption may be incorrect, according to David Jablonski of the University of Chicago, as he reports in a recent research article in *Science*. There is a qualitative as well as a quantitative distinction between background and major extinction, he says, which influences the shape of evolutionary history in unusual ways.

Based on an examination of certain marine organisms that faced the end Cretaceous extinction some 65 million years ago, Jablonski has drawn up lists of characteristics that affect species survival during normal times and through mass extinctions. It seems that those characteristics that permit species to proliferate during normal periods become irrelevant when major extinction events come around.

During these events a different set of criteria become important for survival, which means that success prior to an extinction event is no guide to a species' fate through such an event. Similarly, just because a species survives a mass extinction does not mean that it is necessarily superior—or better adapted—than related organisms that are hit hard. In other words, says Jablonski, "Evolution is channeled in directions that could not have been predicted on the basis of patterns that prevailed during background times."

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For instance, placental mammals came through the end Cretaceous extinction 65 million years ago and flourished splendidly, at the apparent expense of the marsupial mammals, a fact that is usually attributed to the "more advanced and superior" form of placental reproduction. Judged by the criteria derived by Jablonski, however, it seems that the marsupials' destiny was determined by factors quite divorced from the success of everyday adaptations.

So, what are these criteria? In the marine bivalves and gastropods of the Atlantic coast of North America that Jablonski studied, there are three, two of which relate to species as individuals and one to species in related groups, or clades.

The first concerns the mode of development, specifically whether a species' larvae are widely dispersed or not. It turns out that species with mobile, dispersed larvae enjoy a greater longevity than those whose larvae are much more restricted. Secondly, a species that occupies a large geographic range is likely to survive longer than geographically provincial species.

Both of these observations from the fossil record are in line with predictions from evolutionary ecology. Specifically, species that occupy broad geographic ranges, either through larval dispersal or by other means, maintain a genetic stability over a wide area, and therefore can withstand local extinctions. By contrast, species that are restricted to small localities will be wiped out by local extinctions.

The third criterion applies to groups of related species, or clades. In this case clades that comprise many species are more long-lived than species-poor clades. Again this is consistent with predictions from statistical tests on the probability of the loss of any particular clade through stochastic processes: the more species there are in a clade the more likely it is to survive the loss of one or two.

Now, when Jablonski examined the fate of species across the Cretaceous/Tertiary boundary of 65 million years ago a very different picture emerged. None of the above criteria had any significant influence on probability of survival through a major extinction event. The one factor that did emerge from the analysis as favoring survival applied to clades, not to individual species within a clade. Clades with broad geographic distribution fare better in major extinctions than provincial clades, irrespective of the number of species in the clade.

This difference in survival between background and major extinctions has far reaching implications, principally because of the different levels at which the influences apply: at the species level during normal times and above the species level at other times.

One consequence of this can be explained as follows. Supposing that a species were to evolve a new and superior adaptation that endowed it with a considerable survival advantage; such a species would probably flourish during times of background extinction. If a mass extinction were to come along, however, the species might well perish, irrespective of the virtues of the novel adaptation. In other words, perfectly good adaptations might be eliminated during major extinctions for reasons quite unrelated to their utility.

Returning to the fates of the placental and marsupial mammals through the Cretaceous extinction, the relative success of the former and relative eclipse of the latter might simply have been the outcome of geographic distribution, not quality of adaptation. According to data currently being collected by William Clemens, of the University of California at Berkeley, the marsupials were pretty much concentrated in circumequatorial regions of the world during the end Cretaceous extinction whereas the placentals enjoyed a much

wider distribution. This difference alone, according to Jablonski's formula, would be enough to predict the relative eclipse of the marsupials and the relative good fortune of the placentals when the crunch came.

Evolution in the classic Darwinian sense favors advantageous adaptations through natural selection, provided they are heritable. This process is the bedrock of times of background extinction. But when a mass extinction occurs selectivity applies at a level above the species and is blind to individual adaptations. Now, it is clearly of some interest to know whether the characteristic that confers survival advantage on a clade is itself heritable. In other words, do geographically dispersed clades give rise to clades that are also preferentially cosmopolitan?

If clade distribution were in fact heritable, one might expect that selection through a series of mass extinctions would favor the emergence of species that combined traits that were advantageous during background extinction with those that improved survivability through major extinctions. Such a combination would be a sure route to success through the history of life. Jablonski believes he can identify some groups of species that appear to have achieved such a combination and are therefore particularly persistent and diverse, but it seems not to be a general phenomenon. His preliminary assessment, therefore, is that geographic distribution of individual clades is not a heritable trait.

Jablonski's observations on the Cretaceous/Tertiary extinction are echoed in preliminary examinations of other major extinctions, although there are some clear differences too. And, as Steven Stanley of Johns Hopkins University points out, there are certain to be many more factors involved in mass extinctions than are mentioned here, any of which might be emphasized during different events. Overall, however, he describes Jablonski's analysis as an extremely useful approach and one that is consistent with some of his own observations in more recent parts of the fossil record.

If the inference of qualitative differences between major and background extinction holds up generally, a new perspective on earth history emerges. "Currently evolutionary history is formulated almost exclusively in terms of pattern and process during background times," Jablonski notes, "but if mass and background extinctions are qualitatively as well as quantitatively different in their effects, then it is the alternation of background and mass extinction regimes that shapes the large-scale evolutionary patterns in the history of life."

The qualitative difference between the two extinction regimes also speaks to the nature and potential cause of mass extinctions. "They are clearly global phenomena," he says, "probably involving worldwide change in climate, seasonality and productivity." Such events are consistent with, but do not prove, catastrophic impacts with extraterrestrial objects. ■ **ROGER LEWIN**

ADDITIONAL READING

D. Jablonski, "Background and mass extinctions: The alternation of macroevolutionary regimes," *Science* **231**, 129 (1986).

Why Do Cancer Cells Resist Drugs?

Cancer cells that become resistant to one drug frequently become resistant to several other unrelated ones

IT happens all too often. A cancer patient will be given a drug such as doxorubicin or Adriamycin and will go into remission. Then, the patient will relapse and will no longer respond to the drugs that originally destroyed the tumor cells. "The basic question," says David Housman of the Massachusetts Institute of Technology, "is, Why does the patient no longer respond to these drugs?"

What scientists suspect is happening in many instances is that the cancer cells that grow back have learned how to foil the drugs. In tissue culture systems developed to study this problem, the drug-resistant cells apparently turn on and amplify genes that allow them to pump the drugs out as fast as the drugs get in. Moreover, once the cultured cancer cells become resistant to one of a group of unrelated drugs, they are resistant to the others as well. This despite the fact that the only thing these drugs, which include Adriamycin, *Vinca* alkaloids such as vindesine and vincristine, and actinomycin D, have in common is that all are poorly soluble in water. Other than that, they are totally different. They are not similar in chemical structure and they act in different ways to kill cells.

This picture of the biochemistry of multidrug resistance is the product of a new consensus among researchers. Several groups of investigators independently studied this problem, using different methods and with different sorts of results. On 9 and 10 December, they met at a workshop at the National Institutes of Health* to compare notes. The conclusion was that they had all come across basically the same molecular explanation of drug resistance.

The first phase of the work began in 1971 when June Biedler and her colleagues at the Sloan-Kettering Institute for Cancer Research grew cancer cells and exposed them to actinomycin D and selected the cells that became resistant. They obtained cells that are resistant to other drugs as well. At the same time, and independently, Victor Ling of the Ontario Cancer Institute in Toronto unexpectedly obtained similar results in the course of trying to select cells with mutations affecting their microtubules. He exposed cells to drugs—*Vinca* alkaloids and colchicine—that bind to microtubules and ended up with cells that are resistant to a variety of anticancer drugs. Since these results echo what happens in patients, Biedler and Victor Ling began pursuing the problem of determining just what is happening biochemically when cells become resistant.

Researchers soon began seeing evidence that these multidrug-resistant cells may not be accumulating the drugs as sensitive cells do. They found that when they put the drug-resistant cells into a drug-free medium, the drugs pour out of the cells more quickly than they are released from sensitive cells. And if they poisoned the drug-resistant cells by giving them substances that prevent them from pumping chemicals across their membranes, the anticancer drugs remain in the cells. If the researchers then remove these poisons, the anticancer drugs come out of the cells. For these reasons, they concluded that the anticancer drugs enter the resistant cells but are then quickly pumped out before they can do any damage.

Meanwhile, Ling was looking for biochemical changes in the cells that corre-

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