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How Astronomy Changed My Life, and Millions of Other Species as Well

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Life in an Eden may not be all that it's been imagined to be.

In fact, there may not much life at all, or at least not much complex life. Darwinian evolutionary theory is composed of two processes: variation and selection. It's only through the constant repetition of these two attributes that all complex life on a planetary surface is evolved.

It may be surprising then to learn that vigorous ecological competition brings evolutionary progress to a halt. When competition is intense and every niche is filled, each species must be optimized for whatever task it's carved out for itself. But the downside is that no species has any room to experiment. Individuals of the species who can't admirably perform their tasks simply don't survive in the midst of such fierce competition.

In this circumstance, evolution on a stable world slows to a halt. It's only during those periods when competitive pressures are released, generally following an environmental catastrophe, that evolution is allowed to explore a variety of new biotypes and evolution once again "advances." The general rule is: "No vacancy, no evolution."

Unfortunately, we know of no better way to create large-scale vacancies than to whack the planet every so often with massive asteroids. These impacts represent the deaths of million of species and trillions of individuals. But they also allow evolution to begin again, but it doesn't start from scratch. Rather it builds its new species from the genetics of the species that survived, thus the episodic catastrophes have a strong tendency to act as "complexity pumps."

With the impact at Chicxulub, the course of life on the Earth changed in an instant. *Painting by Don Davis, courtesy of NASA*

Perhaps even more interesting is the thought that the groups of animals that evolve to fill the now empty niches are more intelligent than those that preceded them.

Andrew Knoll, a paleontologist at Harvard, has asked, "What does paleontology contribute to evolutionary biology?"

One answer he gives is that paleontology obviously provides a direct historical record of evolution, one that includes organisms such as trilobites and dinosaurs, organisms whose existence would not easily be inferred on the basis of studying modern animals alone. But Knoll argues that paleontology does more than that. What it truly does is to inform us about the nature of evolution on an active planetary surface.

Beginning in the 1970's, a number of paleontologists began to challenge the notion that the populational genetic processes of standard evolutionary biology are sufficient to completely explain the evolution of life on earth, an idea most clearly spelled out by their dictum, "*Macroevolution is decoupled from microevolution.*"

The iridium layer in the Italian Appenines, marked with an Italian coin. The layers of rock below the coin belong to the Mesozoic (“middle life”). The layers above are of the Cenozoic (“recent life”).

Evolution is not a process that operates only through time; there exists a profound spatial component as well. As species increasingly better learn their environments, they simultaneously become bound to those environments. Species diversification, the evolution of complexity and the evolution of intelligence are all similar questions interwoven onto a biogeographic tapestry, governed greatly by a planet's obliquity, eccentricity, internal heat and position in its solar system.

Evolutionary ecology has been slow to recognize the importance of these geographical and astronomical constraints on the evolution of life on Earth, but the last two decades have seen a fundamental shift in that regard. Perhaps the most significant event in turning people’s opinion was Walter Alvarez’s discovery of an iridium layer in the Umbrian mountains of Italy, exactly synchronous with the disappearance of the dinosaurs.

The initial resistance to the asteroidal extinction hypothesis being the cause of a worldwide extinction was intense and immediate from the very beginning. The first public presentation of Walter Alvarez's thesis of the K/T boundary being caused by an asteroidal impact was at the American Association for the Advancement of Science Meeting in Washinton, DC in 1982. By chance, I happened to be there. I was in the audience, in the mezzanine of the auditorium at the Hilton where the meeting took place.

When Walter gave his talk, the front row of seats directly under the stage was populated by a row of very well known paleontologists. When Walter finished speaking, that row simply erupted, almost to the point of rioting. The reason for the reaction was that biology and geology had been fighting for 150 years against the Catastrophism associated with Biblical literalism. The philosophy that underpins modern geology is

Uniformitarianism, the idea that the natural processes operating in the past are the same as those operating today, but here was a direct assault to that presumption.

Alvarez politely listened to what they all had to say, and when they had finished, he said, "Look guys. It's only an hypothesis, but here's what the data say," and he repeated the data again.

I was very impressed by how he conducted himself.

At the time of his talk, Walter only had the data that he had personally gathered in the Umbrian Apennines, along with the new data gathered by geophysicist friends at Los Alamos National Labs in the Raton Basin. The Los Alamos geophysicists found the same iridium anomaly layer in New Mexico, and this was unmistakable evidence that the iridium layer was a marker of a global catastrophe. It was only few years later that the large Chicxulub crater was discovered under the waters off Yucatan by a PEMEX oil exploration team, providing convincing evidence that the hypothesis was accurate.

Since then, the notion that impacts have been changing the course of life on this planet has moved from realm of wild speculation to the hypothesis most often invoked first to explain the major transitions in the composition of life on this planet.

Although the fossil record indicates that a number of catastrophic extinctions have occurred over the past 600 million years, the two large mass extinctions occur at the Permian-Triassic (P/T) and Cretaceous-Tertiary (K/T) boundaries, 250 and 65 million years ago. These boundaries represent such significant transitions in the history of life on this planet that they divide the fossil history into three distinct eras: the Paleozoic ("ancient life"), the Mesozoic ("middle life") and the Cenozoic ("recent life").

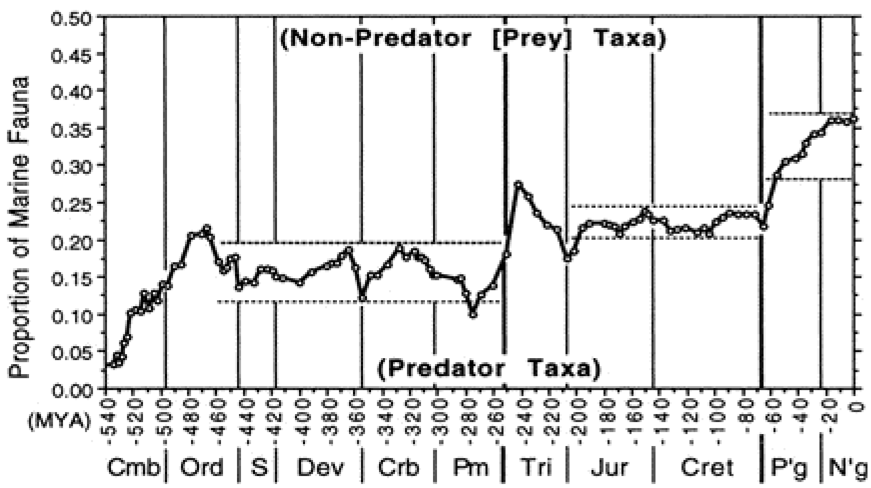
An asteroidal impact has been positively associated with the K/T boundary, but the P/T boundary is much less certain. Nonetheless, an impact is a leading contender for its explanation as well.

The tiny mammal *Hadrocodium* from the early Jurassic (200 million years ago). *Hadrocodium's* skull demonstrates that it is very advanced for its early age. *Illustration by Mark A. Klingler, Carnegie Museum of Natural History*

It often surprises people to discover that mammals are older than the dinosaurs. The dinosaurs arose following the P/T extinction event and disappeared with the K/T impact. But for all of those intervening 190 million years and before, tiny protomammals darted beneath the feet of the dinosaurs. When the dinosaurs disappeared in an instant, the world was left open for the mammals to fill.

In a very real way, the meek did inherit a new Earth, went forth, were fruitful and multiplied. But even more relevant to our story, the mammals experienced the very rapid evolution that is associated with all organisms as they undergo adaptive radiations into novel adaptive zones. Every bit of evidence suggests that these new mammals were more intelligent than those that preceded them.

Richard Baumbach and Andrew Knoll have recently performed a very interesting analysis using the late Jack Sepkowski's data. They classified marine invertebrates (clams and the like) by their most gross characteristics: whether they were mobile or sessile, predator or prey, and whether they were well buffered from their environments. What they found was that following both of the two primary catastrophes reset these characteristics in the surviving organisms. With each catastrophe, the survivors became more mobile, more disconnected from the vagaries of the environment, and more predaceous.



The ratio of predators to prey organisms seen in the fossil record. Following the two great catastrophes of the Permian-Triassic (Pm-Tri) and Cretaceous-Tertiary (Cret-P'g) boundaries, life advanced in a step-wise manner to become more predaceous, and thus presumably more intelligent.

It's this last characteristic that is of special interest. Intelligence is a quality associated with predators. While Baumbach and Knoll's analysis only dealt with marine invertebrates, evidence suggests that the same pattern existed for the terrestrial species as well.

It thus may be no overstatement to say that our modern capacity to build computers and spaceships is a direct consequence of asteroidal fragments being repeatedly hurled at Earth, and without these "kicks in the pants," we wouldn't be we.

Next month: Looking for Life in All the Wrong Places