INSTITUTE OF CURRENT WORLD AFFAIRS

DRP-4

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How Feathers Killed the Dinosaurs

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Dear Peter:

I am devoting this letter to the further elaboration of my views about the extinction of the dinosaurs. You may remember that I touched upon this subject in an earlier report (DRP-2.) It normally takes scientific ideas a long time before they surface into popular literature. Occasionally, however, a proposal is so outlandish it quickly hits the press, long before its value has been adequately examined. In other words, these ideas have such high entertainment values that their validity is only of secondary concern. Such is the case with the "theory" that a horrific celestial event -- the collision of a large asteroid or comet with the earth -- doomed the dinosaurs. According to the hypothesis, the tremendous energy released by the collision blasted a cloud of debris, including ash and smoke from incinerated organisms, into the stratosphere. The cloud was so dense it blocked light from the sun and produced a "proto-nuclear" winter; for a period of at least several months there was enduring darkness and cold that extinguished the dinosaurs and initiated a major change in the world's ecosystem.

Before I continue, it should be known that the word theory has a very narrow scientific definition. Theories have been verified, thus a theory is not simply a conjecture or speculation. These latter concepts are known as hypotheses and are the grist of a working science. Once an hypothesis is verified, it can support or even become a full fledged theory.

Over the past several years a variety of media have given considerable attention to the Asteroid-collision hypothesis. The prospect of the earth being injured by a wayward piece of cosmic rock at the very end of the Cretaceous, a geological period that

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ended about 60 million years ago, was irresistible to the press, and the idea even rests on firm scientific ground. The first to discover evidence of this disaster was a group headed by Walter Alverez in 1979. They found a layer of iridium directly above the last marine sediments of the Cretaceous period. Certain plankton in those sediments disappear above the iridium layer and thus are thought to have become extinct at that time. Now, after much scientific scrutiny, it seems likely that the iridium did come from space. These are the facts and yet the essential evidence is still lacking -- evidence that correlates the marine iridium and underlying extinct plankton layers with extinctions on dry land.

Even Walter Alverez recognized that the fossil record of terrestrial species would either support or destroy the collision hypothesis. In fact the fossil evidence of terrestrial plants, the best record of what occurred on land, forced a major revision of Alverez's first proposal. He and his coauthors discussed the issue in a later article entitled, "Current status of the impact theory for the terminal Cretaceous extinction" (1982, Geological Society of America Special Paper 190).

> "In the dust scenario, we suggested that darkness would last a few years....This was based on a report of the Royal Society of London (1888) which came to that conclusion after a study of the duration of colored sunsets after the Krakatoa explosion of 1883, and which was the only relevant information we had available at the time. Hickey (1981) [a tropical plant paleobiologist] strongly objected to the dust scenario. A few years of darkness should have produced drastic extinctions among plants of the tropics, which do not have the capability of remaining dormant for that length of time, and Hickey did not find these extinctions....Milne and Mckay (1981) calculated that a few months of darkness would produce approximately the degree of extinction among oceanic phytoplankton that is observed in the oceanic [fossil] record....Hickey (personal commun., 1981) concluded that a few months of darkness could not be rejected on the basis of survival of tropical plants."

This indecision over the duration of the dust cloud only partially addresses the weaknesses of the collision hypothesis. Another consideration is that it is difficult to imagine let alone speculate about how dinosaurs could be the only major terrestrial group affected by the catastrophe. On a medical level this is comparable to saying that cyanide could kill all types of cancer cells but no other tissue. Alverez and his colleagues were on the right track when they considered how extended darkness might affect plants. One can only wish that they had fully pursued this line of reasoning by including in their postulate other terrestrial organisms.

To diverge momentarily from this discussion I would like to say that I am a cynic when it comes to believing most new biological "theories." My experience with academia is that senior scientists all the way down to struggling undergraduates are under considerable pressure to produce noteworthy research and theories. To be able to foment biological argument for even a short time can help secure a position at a major institution. This is most easily accomplished by avoiding damning evidence, and it matters little if these arguments soon fade.

In an earlier report (DRP-2) I briefly considered the relative hardiness between dinosaurs, birds, and mammals as a test of the validity of the collision hypothesis.

> "Which animals would have survived? This is a problem of energetics. The animals that used up their stores of energy most quickly would have died. Relative to mammals, the dinosaurs had a distinct advantage, as do all reptiles. To begin with, their basic metabolism is about one sixth of a reptile's. That means a dinosaur that is the same size as a mammal needs one sixth the amount of food to survive. Also dinosaurs, like mammals, would have been able to hibernate as soon as they got cold [actually reptiles are better at hibernating than mammals]. There would have been a large number of small and medium-sized dinosaurs that could have found shelter. One can only conclude that dinosaurs would have been as likely or even more likely to survive a "protonuclear winter" as mammals.
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> The coup de grace for the collision hypothesis is that it totally fails at predicting what would happen to birds. Birds are animals that are literally teetering on the brink of death. They forage in the daytime, every day they need large amounts of food relative to their body size just to survive, and they don't hibernate. Within a week after the cosmic blast birds would have been totally extinct, yet nearly all major groups of birds survived the Cretaceous and rapidly proliferated. The very existence of birds today proves that there could not have been a protonuclear winter for at least one hundred and fifty million years, which in turn means a comet could not have caused widespread and general extinction of any of the planet's recent life."

A more logical, but perhaps less spectacular explanation for the extinction of marine organisms is that something poisoned them without affecting the terrestrial biota. Much more attention must be given to this possibly. Knowledge about past disturbances of sea water might provide insight into the consequences of worldwide human pollution of the oceans.

To summarize this discussion: 1) There is no fossil evidence that dinosaurs simultaneously died when iridium showered on the earth. In fact, the fossil record suggests that dinosaurs were going extinct for millions of years prior to that event. 2) If there was rapid, wholesale destruction of terrestrial biota then one would expect to see evidence of this in the fossil record. This evidence does not exist. 3) The theory assumes a magical force that somehow kills dinosaurs without driving other more sensitive organisms to extinction. It is on this last point that the collision theory dies as a hypothesis and emerges as just another of the many imaginative stories about a past that we can never fully understand.

To my mind the following hypothesis is the best explanation at this time for the ecological changes that reshaped the ancient world and undid the dinosaurs. This hypothesis first appeared in Science (May 6,1977) in an article entitled "Ecology and Evolution of Flowering Plant Dominance." It was written by Philip Regal who was from the department of ecology and behavioral biology at the University of Minnesota. The article was lengthy and technical, so I will only summarize what he said. Also I have added a few twists of my own to the proposal. (Part of this material is extracted from In Tropical Treetops my photographic-adventure book that will be published in September by Simon and Schuster. This book has been mentioned in previous reports under the title Life at the Top.)

According to Charles Darwin one of the greatest mysteries of the paleontological world was the evolution of flowering plants, or angiosperms. The evolutionary record of angiosperms is spotty up until the Cretaceous at which time the numbers of species began to increase. By the late Cretaceous, the numbers of angiosperm species skyrocketed -- numerous new species suddenly and inexplicably appeared in the fossil record. Darwin was stumped by this event calling it an "abominable mystery." The remark has often appeared in scientific literature and has been latched onto by Creationists who saw the angiosperm radiation as evidence of a deity's direct involvement in speciation. With the arrival of Regal's paper there was finally a reasonable explanation for the remarkable increase in the diversity of angiosperms.

In the early Cretaceous (120 mya) nearly all the essential actors of the coming revolution were present. The flora and fauna was an odd mixture of old and new. Hungry primitive birds flapped feebly into the skies; pterosaurs glided high over hills, mountains, and cliffs; large and small dinosaurs roamed the earth and small, ravenous mammals stalked insects at night. A few species of primitive flowering plants and their insect pollinators inhabited the canopy and basement habitats of jungles that were dominated by tree ferns and gymnosperms such as conifers, cycads, and gingkos. But according to Regal's theory, the scene would soon change as flowering plants forged a new ecological relationship with evolving birds. At this time birds had weak powers of flight and ate primarily insects; fruit had not yet evolved.

A new form of energy was beginning to materialize, almost out of thin air, through coevolutionary processes. Feathered, gliding reptiles gave birth to birds that had an ever-increasing need for energetic foods to fuel increasingly powerful flight muscles. Voracious appetites due to increasing metabolic rates made primitive birds reliable visitors to angiosperms where they found swarms of insects around flowers and seeds. The exact time when seeds of flowering plants gained a nutritious, energy-packed covering is not known, but by the close of the first half of the Cretaceous, a solid link seems to have been forged between birds and evolving fruit. Plants had "stumbled" onto the idea of providing evolving birds with easily digestible energy packets in the form of concentrated sugar. After being lured in, a bird could be exploited; seeds would stick to feathers, bills, feet, or were swallowed then carried off to favorable growth sites. The potent ecological consequence of this relationship was that angiosperms were in the position of becoming the planet's major power source for the evolution of a spectrum -- terrestrial, arboreal, and aerial -- of warm-blooded animals.

Just as mankind's capacity to use the "free" energy of coal and oil fueled rapid cultural change, the formulation by angiosperms of a new ecological energy equation shook the foundation of ancient life. The dominant, primitive plants of lowland jungles that relied on less effective wind dispersal began to disappear as angiosperm seeds were quickly transported by birds to any spot in the forest. As old gymnosperms fell and formed gaps, angiosperms increasingly became the first colonists. Bird-dispersed seeds also helped angiosperms escape from seed-eating insects and other predators that congregated below tree crowns. Gymnosperm seeds, which were wind dispersed and relatively immobile, became easy victims of these predators. Pollination by insects helped angiosperms to maintain reproduction between mates separated by long distances. Birds, flowering plants, and insects acted in synergy to intensify each other's effectiveness. Together they continued to evolve and this catapulted earth's terrestrial ecosystem into an era of rapid evolution.

By the late Cretaceous (60 mya) angiosperms increased in number and diversified into all available niches. This forced gymnosperms to become more widely spaced and ultimately meant that as angiosperms continued to proliferate, wind pollination, which depended on dense populations of the same species, would fail. Primitive, non-angiosperm plants, the basis of the food web for a number of lumbering dinosaurs, were becoming extinct and taking the reptilian herbivores and their monstrous predators with them. The age of dinosaurs and gymnosperms was over; the age of birds, angiosperms, and mammals had begun.

The age of mammals in itself has been a major biological puzzle. Many scientists outside of ecology have been reluctant to accept the fact that competitive interactions can and do change the earth's biotic face. They claim that if mammals were superior to reptiles, mammals would have replaced dinosaurs in the early Cretaceous or Jurassic. Instead primitive mammals lived alongside the dinosaurs for tens of millions of years as small insectivores. Comparing reptiles to mammals is like comparing apples and oranges, they are not ecological equivalents. There is no reason to suppose that mammals were superior to reptiles or competed with them in any way. It is best to assume that reptiles were better adapted to the biotic environment of their time. The question is not why mammals lived alongside reptiles without coming to dominate them, but what in the biotic environment stopped mammals from proliferating?

Mammals, like any class of organisms with a vast evolutionary potential, had to "wait" for an opportunity to evolve. Like birds, mammals had become warm-blooded before the arrival of angiosperms and "found" themselves in an energy poor world where resources were suited to cold-blooded (ectotherms) reptiles. In all probability the high fiber, leafy, gymnosperm diets in existence at that time would not adequately feed today's large and small mammalian herbivores, and for physiological reasons it seems that primitive mammals would be no different. For example, the leafy angiosperm diets of most ungulates such as deer, cattle, sheep, pigs and horses are supplemented with grains. Without grain, and other angiosperm parts, large warm-blooded herbivores would find survival impossible.

Sloths and koala bears are good examples of how a strict leaf-eating diet affects the mammalian metabolism. A sloth's metabolism operates at 42% of the expected rate for a mammal of its size. Sloths cannot digest their food fast enough to always maintain high body temperatures, so on cold days their temperatures fall several degrees. A similar condition exists for koala bears. To subsist on leaves, these warm-blooded animals have undergone reverse evolution; by partially giving up homeothermy, they have taken a step toward becoming cold-blooded. The Hoatzin, a bird of the Amazon basin that exists on a leafy diet, has nearly lost the ability of powered flight. This suggests that diet and the amount of energy that could be extracted from prehistoric food played an integral part in determining the type of organisms that came to populate the earth. Gymnosperm leaves and other dominant vegetation prior to the late Cretaceous were notably more fiberous and less edible than grass, shrub, and tree leaves. This strengthens the conclusion that ancient forest vegetation would have been a poor springboard to widespread warm-bloodedness even among birds. In ancient times warm-bloodedness was fueled by eating insects, scavenging, and living near the sea or lakes where fish were plentiful. As a result mammals could not become large-bodied elements of ancient terrestrial vertebrate communities.

Why then didn't mammalian carnivores that ate dinosaurs evolve in the Jurassic? Some recent and surprising discoveries about tropical American carnivores may supply an answer. Daniel Janzen, in his book Costa Rican Natural History, states that tropical carnivores are highly frugivorous. "The ... Carnivora (of Costa Rica) comprise six felids, two canids, six species of procyonid, and seven species of mustilid. All except the otter (Lutra longicaudus) and mountain lion (Felis concolor) are known or alleged to consume large amounts of fruit." These animals are excellent dispersers since their gut does little damage to seeds. Contrary to what we have been taught, angiosperm fruit probably has always been an important part of carnivore diets. These animals appear to have been able to evolve solely because of the growing availability of fruit after the late Cretaceous when angiosperms were diversifying. In my view it is highly probable that the paucity of energetic plant foods and a preponderance of high fiber foods prior to the late Cretaceous stopped mammals and birds from becoming important components of that ancient ecosystem.

This view of ancient forests as being energy poor also explains another feature of dinosaurian biology. A direct extrapolation from our knowledge about mammalian body size versus food quality provides a possible reason for why dinosaurs tended to be large. For thermodynamic and physical reasons it is known that as animals become larger, they are more able to process large volumes of low quality food to survive. Thus, the largest herbivorous mammals also tend to eat the poorest foods. So it is not surprising that the largest terrestrial herbivores of all time fed on plant communities that were notably much more fiberous and of lower food quality than today's angiosperms (grasses are angiosperms).

Regal's theory, with minor elaboration, is better than any in understanding the complex ecological events that must have taken place during the late Cretaceous. Other theories either ignore or or fail to incorporate the large amount of knowledge that has been gleaned from studies of tropical biology over the past twenty years. In order to be credible, new "theories" must do so while systematically accounting for what is found in the fossil record.

Sincerely,

Don

Donald R. Perry

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