

COVER STORY

Did Comets Kill The Dinosaurs?

A bold new theory about mass extinctions

In the evening around the Leuschner Observatory in Lafayette, Calif., a few enterprising rattlesnakes slither out to toast themselves on the asphalt parking lot, which retains the warmth of the sun long after the air has cooled. Inside, a 30-in. telescope begins a laborious computer-controlled search of the heavens, covering only a tiny patch of sky during the next six hours of darkness. And the following day, at the nearby University of California campus in Berkeley, Physicist Richard Muller, like a seer divining entrails, scrutinizes the new batch of video recordings from Lafayette. He seeks a sign of a dim star that many scientists think does not exist: Nemesis, the death star, a possible companion to the sun.

Some 400 miles to the southeast, atop snow-covered Mount Palomar, Eugene Shoemaker, a geologist on leave from the U.S. Geological Survey, and his wife Carolyn, an asteroid astronomer, scurry around the unheated dome of the 18-in. Schmidt telescope. They photograph the sky in four-minute exposures, hunting for fast-moving objects against the background of the fixed stars. So far their Palomar study has identified 25 asteroids that cross the earth's orbit, bringing the known total to 60. Asteroids like this, they think, have occasionally crashed into the earth with catastrophic consequences, and they strive to calculate how frequently these inopportune meetings occur.

As the Shoemakers chart the asteroids' travels, astronomers at the Jet Propulsion Laboratory (JPL) in Pasadena, Calif., hunt for another elusive creature of the night: the legendary tenth planet, or Planet X. They comb through the tangled statistics and images transmitted in 1983 from the now defunct orbiting Infrared Astronomical Satellite (I.R.A.S.), struggling to find a single pinpoint source of radiation that over a six-month period has shifted in a particular pattern among the fixed stars, as only a nearby planet can do. Says Daniel Whitmire, a University of Southwestern Louisiana astrophysicist who is involved in the search: "There's a chance it's already been recorded and is awaiting discovery right now."

These quests are all part of the controversy and ferment that have been bubbling through the scientific community since the rise of a spectacular new theory that attempts to explain the mass extinctions—most notably the one in which the dinosaurs perished—that have punctuated the history of life on this planet. Every 26 million years or so, the theory holds, a rain of comets that lasts hundreds or thousands of centuries bombards the earth. The impact of some of the larger comets spews enough debris into the atmosphere to block the sun for months. As the skies darken, temperatures on the ground plummet and the majority of existing plant and animal species perish.

Galvanized by this radical proposal, researchers are hunting for an agent that could explain the apparent clockwork regularity of the celestial barrages. Some suggest that a companion star to the sun periodically comes close enough to nudge comets gravitationally out of their natural habitat—a cloud of comets that circles the sun far beyond the orbit of Pluto—sending them hurtling toward earth. Others assign that role to Planet X, while some insist that the slow, bobbing ride of the sun and its planets around the Milky Way galaxy is responsible. Whatever the details, declares Paleontologist J. John Sepkoski Jr. of the University of Chicago, the evidence for periodic mass extinctions "very strongly implicates an extraterrestrial mechanism."

If the theory is correct, the next catastrophe will not occur for at least 13 million years. But the effect of the new concept on science and scientists has been much more immediate. One measure is the ferocity of debate it has generated in the past few months among eminent researchers, at conferences and in the letters-to-the-editor columns of major newspapers and staid journals alike. Supporters of the Milky Way proposal dismiss the Nemesis notion as "unlikely" and "ad hoc," and death star advocates are scornful of the galactic concept. Many consider all the newfangled extraterrestrial scenarios to be half-baked takeoffs of H.G. Wells. Says an indignant Dewey McLean, a paleontologist at Virginia Polytechnic Institute: "It's science gone absolutely bonkers."

Halley's comet blossoms in false color in this computer-enhanced version of a 1910 photo

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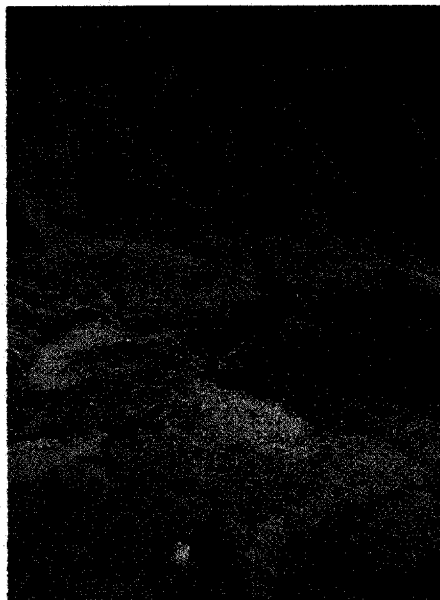
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The controversy has engulfed not only astronomers, geologists, paleontologists and astrophysicists but even evolutionary biologists. If the cyclic theory is true, the biologists argue, many assumptions about the course of evolution on earth—and even the likelihood of finding complex life forms on other planets—will be overturned. Says Whitmire: "Just the possibility that life here has been controlled by an astronomical event is very far reaching."

In one sense, the current fights over extinction theories are merely the latest variation of a venerable tradition that dates back to the early 19th century, when a growing corps of paleontologists and geologists had determined that the world is not the static Eden-like meadow of legend. At least intermittently, they concluded, it is an unstable, dangerous place, where vast numbers of species, like the giant mastodons, mysteriously disappear. Eventually, after analyzing the bones long thought to be the remains of dragons, they pieced together the almost more fantastical story of the dinosaurs and their inexplicable demise. They zealously dug up fossils of mysterious plants, insects, small animals and marine organisms, compared them with living ones, and pondered their disappearance from the earth. Had it been sudden and catastrophic, or gradual?

Some Victorian scientists viewed the



HARVEY FOSTER—NATIONAL MUSEUM OF NATURAL SCIENCES, CANADA

Fossil bone in Alberta's Dinosaur Park

Fanciful tales and remains of dragons.

discoveries as evidence of a primordial flood, possibly Noah's. A few linked extinctions to the fury of volcanoes; their conjecture was based on the extraordinary explosion in 1883 of Krakatoa, a volcano between Java and Sumatra, which darkened the skies and triggered a giant tidal wave that drowned 36,000 people.

In the end, however, most of the scholars responded to the lure of Darwin, insisting that creatures die out because they are no longer fit to survive and must give way to the supremacy of the new. That argument seemed to apply particularly well to the dinosaurs, which were denigrated as being too big, too slow, too pea-brained and too cold-blooded for their own good.

As geology became more precise, scientists determined from the fossil record that at least five great dyings—and numerous smaller events—have occurred in the past 600 million years. Among the more significant: the Cambrian disasters some 500 million years ago, when many species of segmented creatures called trilobites disappeared from the seas they once dominated; the biggest of the extinctions, the Permian cataclysm of 248 million years ago, when up to 90% of all marine species died; and the late-Cretaceous event 65 million years ago, which saw the destruction of the dinosaurs and many other groups of species, including the microscopic organisms responsible for creation of the white cliffs of Dover. The effects on evolution were profound. "In wiping the slate clean," says Muller, "these catastrophes opened up ecological niches and prevented stagnation."

Yet for all the evidence of destruction, scientists could not figure out where the eraser was hidden. Geologists naturally

Arizona's Barringer Meteorite Crater, punched out some 50,000 years ago by an iron-rich meteorite, is 550 ft. deep, 3,900 ft. across

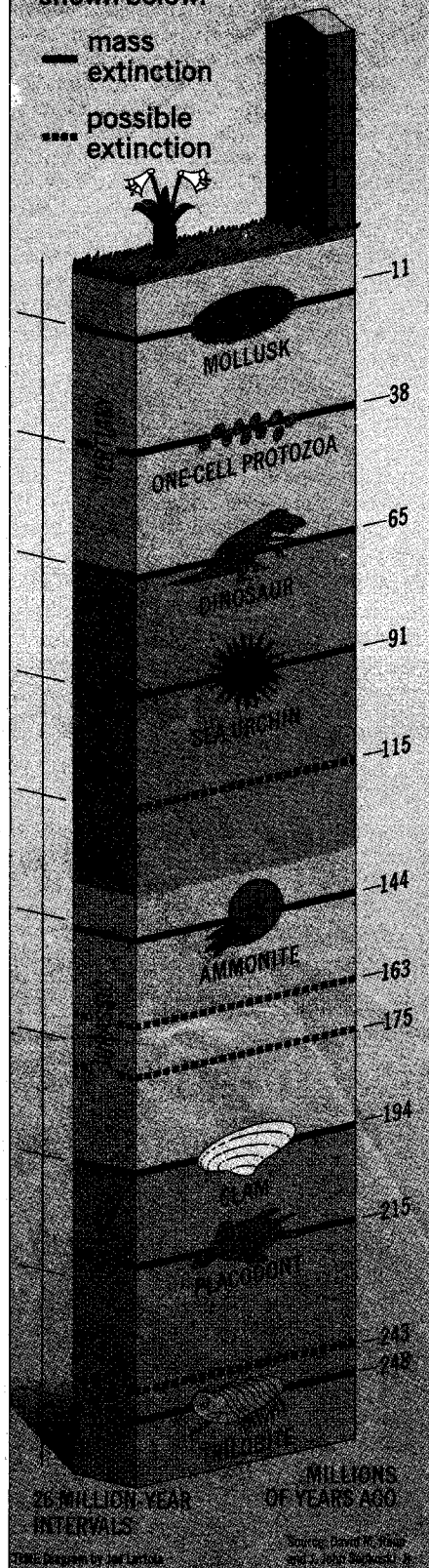


D. J. RODDY AND K. ZELLER—U. S. GEOLOGICAL SURVEY

A ROCK RECORD

Fossil evidence suggests that a mass extinction occurs every 26 million years or so, wiping out, among others, some families of the creatures shown below.

— mass extinction
 - - - - possible extinction



Walter and Luis Alvarez peering through a transparent star dome in Berkeley, Calif.

looked to the earth for explanations, citing changes in climate or sea level. By the mid-1960s, scientists had concluded that the planet's tectonic plates are continually on the move, bumping and grinding against each other to produce earthquakes and mountains, or separating to tug apart land masses and rearrange the oceans. When sea levels change, they reasoned, animal habitats in low-lying areas may be destroyed, or the climate farther inland may grow more extreme.

What is more, the restless tectonic plates spawn volcanic eruptions, which spew carbon dioxide into the air. The increase in atmospheric carbon dioxide results in a greenhouse effect, which traps the sun's energy, causing temperatures on land and in the sea to rise markedly. Conversely, crustal movement may allow frigid ocean currents from the poles to invade tropical waters, leading to a worldwide drop in temperatures. Those species that cannot adapt to the earth's erratic behavior simply succumb. To many paleontologists, as well as geologists, it seemed to make sense.

Serious questions remained, however. Why, for example, were extinctions so selective, devastating some species while leaving others virtually unscathed? Try as they might, scientists could not devise a single elegant theory to tie the loose ends together. They were about to get what they asked for, but like the British author W.W. Jacob's infamous monkey's paw (which granted wishes—at a price), it would not be an unsullied blessing.

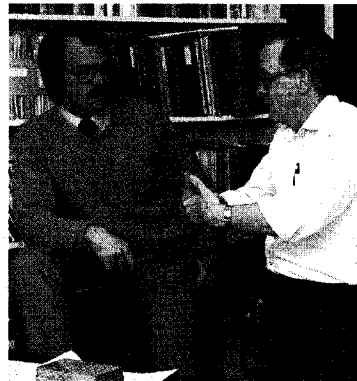
The revolution began with an unassuming element known as iridium, a rare and hard silvery-white metal related to platinum and gold. In the spring of 1977, Geologist Walter Alvarez of the University of California, Berkeley, was carefully chiseling through the rocks outside Gub-

bio, a medieval Italian town halfway between Florence and Rome, seeking clues to continental drift. Gubbio has long been an appealing site to geologists and paleontologists because its rocks provide a complete geological record of the critical boundary line between the end of the Cretaceous period, when the dinosaurs disappeared, and the Tertiary period, which followed it.

As he chiseled, Alvarez was struck by a configuration of sediment layers, which resembled a sandwich in stone. The bottom or older layer consisted of Cretaceous limestone, which was full of tiny fossils. On top was a second slice of limestone, from the Tertiary period, almost devoid of these fossils. Like other samples of rock from that era, it showed that the creatures alive during the late Cretaceous period

had, by geological time scales, suddenly disappeared. In between the limestone layers was a dull red layer of clay about half an inch thick, first discovered by an Italian paleontologist around 1960.

Alvarez, his curiosity aroused, shipped samples of the sediment back to the U.S. and showed them to his father Luis, a Nobel-prizewinning physicist also at the University of California, who had the



Sepkoski and Raup pondering cycles

clay analyzed. To everybody's surprise, it turned out to be 30 times as rich in iridium as normal rocks. The Berkeley team knew of only a few places where such high concentrations of the rare element might occur: in the earth's core, perhaps 2,000 miles belowground; in extraterrestrial objects like asteroids (or their fragments, meteors) and comets; or in the cosmic dust drifting to earth from a nearby supernova (exploding star). The core material seemed too deep to come to the surface, and further analysis ruled out a supernova as the source, so father and son concluded that the iridium had been left by a giant

asteroid hitting the earth at the end of the Cretaceous period.

The Alvarezes did not stop there. Basing their calculations on the atmospheric consequences of the explosion of Krakatoa, they roughly estimated how much dust the impact of the asteroid would have thrown into the atmosphere, how long sunlight would have been blocked from the earth's surface, and what kinds of life would have been the most gravely affected by the climatic changes. They decided that plants, totally dependent on the sun for photosynthesis, and a variety of marine organisms would have died first, followed by the land animals highest on the food chain, the dinosaurs. Eventually the iridium-enriched debris, circulating around the world in the atmosphere, would have settled like a sprinkling of black snow over much of the globe. (It was the Alvarezes' theory that helped to shape the now familiar concept of nuclear winter.)

Journeying to Denmark, another site where the Cretaceous geological record is complete, Walter Alvarez gathered corroborating samples of iridium and received still more from colleagues working at a third site on the other side of the world, in New Zealand. The evidence seemed overwhelming. In 1980 the Alvarez team finally published its results in the journal *Science* and stirred up some scientific debris of its own. Says Paleontologist Leo Hickey, director of the Peabody Museum of Natural History at Yale: "My first thought was this is one of Walter's practical jokes."

Other scientists, drawn into the fray by the Alvarez conjecture, have since suggested that a large comet might have similar consequences. Los Alamos Weapons Experts Stirling Colgate and Albert Petschek computed that a comet six miles in diameter hitting the earth would have an effect 100,000 to 1 million times as great as a large nuclear explosion, and would blow a 100-sq.-mi. hole in the atmosphere.

Several researchers rushed forth to deny any extraterrestrial origins for the iridium, attributing it first to a gradual process of sedimentation that concentrated the metal. Later an old favorite was proposed—volcanic eruptions, which might have forced iridium from the mantle to the surface. The most recent naysayers are Dartmouth Geologists Charles Officer and Charles Drake, who reported in *Science* on their studies of two other telltale elements in the clay boundary between the Cretaceous and Tertiary periods. They found that the levels of arsenic and antimony correspond to decidedly terrestrial, not cosmic, concentrations.

One of the Alvarezes' staunchest critics has been William Clemens, a paleontologist at the University of California, Berkeley. After systematically sampling parts of the eastern Montana area, he declared that the layer of iridium and the bones of the last surviving dinosaur were

Incident at Tunguska

The fireball that rose over a conifer forest in the remote Stony Tunguska River basin in central Siberia on the morning of June 30, 1908, reached an altitude of twelve miles, and the blast was heard hundreds of miles away. Those closest to the explosion, the townspeople of Vanavara, 40 miles away, felt a wave of intense heat; windows cracked, objects fell from walls, and one man sitting on his porch was thrown several yards and knocked unconscious. Trees were flattened and scorched over an area of several hundred square miles, their felled trunks all pointing away from the epicenter.

Even now, more than three-quarters of a century after the spectacular event at Tunguska, scientists are certain only that a celestial intruder was responsible. Some argue that it was an asteroid as large as 500 ft. across and weighing 7 million tons, which rapidly heated as it entered the earth's atmosphere and exploded about five miles above ground. Others believe it was a small comet. Whatever the cause, the destructive power of the object from space rivaled that of a very large nuclear warhead; scientists gauge the explosion at twelve megatons.

Although both comets and asteroids can wreak considerable havoc if they collide with the earth, they are of very different natures and origins. Asteroids are rocky chunks that range in size from pebbles to a mammoth named Ceres that astronomers estimate to be as much as 600 miles across. Most of them orbit the sun in a belt between Mars and Jupiter and are thought to be either remnants

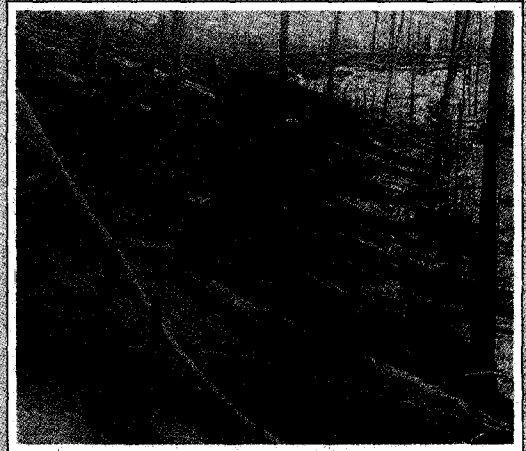
of a planet that disintegrated early in the life of the solar system or celestial building blocks that never quite coalesced into a planet. Occasionally an asteroid is slowed in its travels, probably by the gravity of nearby Jupiter, and tugged into an orbit that sends it closer to the sun and the inner planets, including earth. And sometimes collisions occur. About 100 of the earth's largest known craters are believed to have been caused by huge asteroids dropping from the heavens.

Comets are more mysterious. Unlike asteroids, which reveal themselves in the form of meteorites that can be pried from the ground and analyzed in laboratories, comets have left no known remnants on earth; they have been studied only from afar—through telescopes. (Scientists hope to unlock more cometary secrets when Soviet, Japanese and the European Space Agency probes fly past Halley's comet in March 1986.)

Most experts agree with Harvard Astronomer Fred Whipple, who characterized comets as "dirty snowballs" consisting largely of ice and mineral-rich dust. Comets are thought to originate in the Oort cloud, a distant shell of icy debris believed to surround the solar system and extend out some 10 trillion miles from the sun. Passing stars sometimes dislodge snowballs from the cloud, which can sprout the classic luminous tails of gas and dust as they plunge toward the sun. Most comets whip around the sun and head back out of the solar system. Some, like Halley's, periodically return. But others crash into the sun or the planets, a fact confirmed in 1979 when a Defense Department satellite photographed a comet plunging to a fiery death in the sun.

Although comets are more ethereal than asteroids, usually quite small and probably never more than several miles in diameter, they often pass earth at speeds greater than 100,000 m.p.h. and thus have great destructive power. Despite the fact that no direct evidence of a cometary collision has been found, the earth has undoubtedly been hit many times by the icy missiles.

If comets do strike in barrages every 26 million years or so, as the new cyclic theory holds, inhabitants of the earth 13 million years from now are in for some trouble. But it is also possible, even probable, that long before that time, astronomers will spot a random, incoming comet or asteroid nudged by the gravity of an outer planet into a direct collision course with the earth.

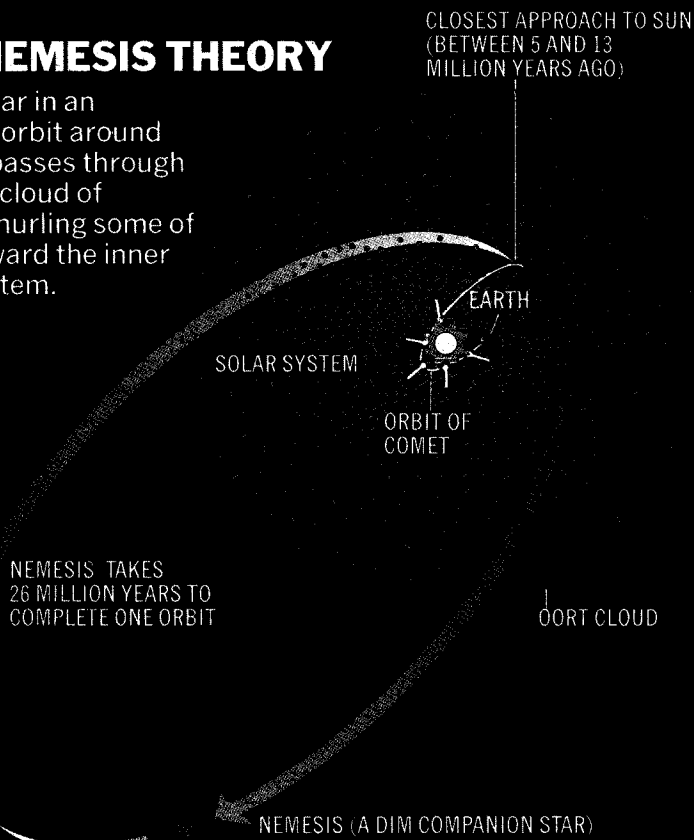


Felled trees at blast site in Siberia

ALAN GARDNER FOR LIFE

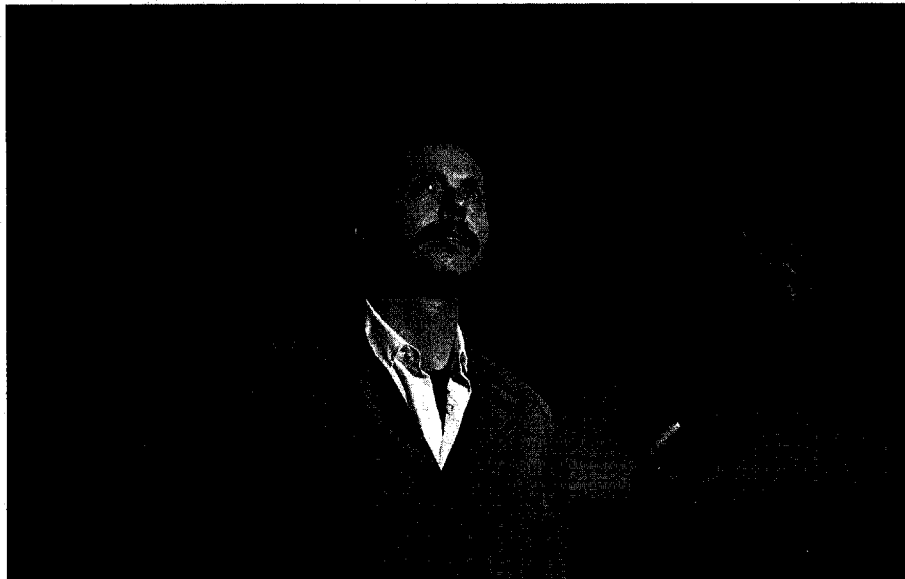
THE NEMESIS THEORY

A faint star in an elliptical orbit around the sun passes through the Oort cloud of comets, hurling some of them toward the inner solar system.



Source: Richard Muller

TIME Diagrams by Joe Lertola



Richard Muller scanning the night sky at the Leuschner Observatory. Is Nemesis there?
Some very powerful object must be directing the flow of traffic.

too far apart to share any meaningful connection. Besides, he asked, why should the mammals have survived any Cretaceous catastrophe? Says he: "If you're going to have a nuclear winter killing off the dinosaurs, why didn't it kill off everything else?"

Nonetheless, the evidence in favor of an impact was rapidly accumulating. Other geologists uncovered similar iridium deposits just above Cretaceous rock beneath the floor of the Atlantic Ocean and under the Raton

basin in northeastern New Mexico. Additional analysis showed that the samples contained ratios of gold and platinum nearly identical to those found in meteorites. Furthermore, other sediment layers containing abnormally high amounts of iridium were discovered under both the Caribbean Sea and the Gulf of Mexico; these layers were deposited around the time of a smaller mass extinction that occurred more than 30 million years ago, at the end of the Eocene epoch. In addition to the iridium anomaly,

the sediments harbored microscopic balls of glass called microtektites, which form in rock when something hits it with great force—further evidence of a major collision. Yet investigators continued to regard the findings from the two time periods as being no more related than, say, separate automobile accidents in Des Moines and Miami. Explains Walter Alvarez: "It seemed to everybody involved that extinctions and impacts should be random in time."

That impression began to change in 1983, when Sepkoski and a colleague, Paleontologist David Raup of the University of Chicago, presented a paper in Flagstaff, Ariz., at a symposium on mass extinctions. The pair had examined data on marine organisms that had become extinct over the past 250 million years, a list of about 3,500 families that included an estimated quarter of a million different species.

Through intricate statistical gymnastics, the two scientists found that most of the dyings fell into as many as a dozen events of varying severity, some of which had previously gone unrecognized as being mass extinctions at all. Then the kicker: the catastrophes were separated by periods of 26 million years. Though many scientists were skeptical, the Chicagoans did receive crucial support from one expert. Erle Kauffman, a paleobiologist at the University of Colorado in Boulder, announced that he had used advanced radiometric techniques to date fossils from a handful of midsize extinctions in the Cretaceous period and found them to be, yes, 26 million years apart.

The implications were compelling. No earthly phenomena, no Vesuvian eruptions, no swelling seas, no ice ages could explain the regularity. Eyes turned heavenward. As Raup and Sepkoski declared in their paper on the subject, "We favor extraterrestrial causes." It did not take long for skygazers, ever an imaginative group, to begin coming up with candidates. Because researchers could not invent a convincing celestial event that would periodically disturb the nearby belt of asteroids that circle the sun between the orbits of Mars and Jupiter, attention turned to swifter and icier astronomical travelers, the comets.

Among the first cyclic mechanisms considered was one already familiar to astronomers: the sun's undulating route around the crowded Milky Way galaxy, an island of some 100 billion stars. The Milky Way is shaped something like a sunny-side-up egg, 100,000 light-years in diameter, with a bulge (the yolk) in the middle and three flat, dusty arms (the egg white) forming a circle around it. Like all its fellow stars, the sun revolves around the galactic center, taking about 250 million years to complete a round trip. As it moves, it bobs up and down through the central plane of the galaxy, where most of the stars and dust clouds are concentrated. Says Michael Rampino, a geologist with the Goddard Institute for Space Studies in New York City: "It's like a

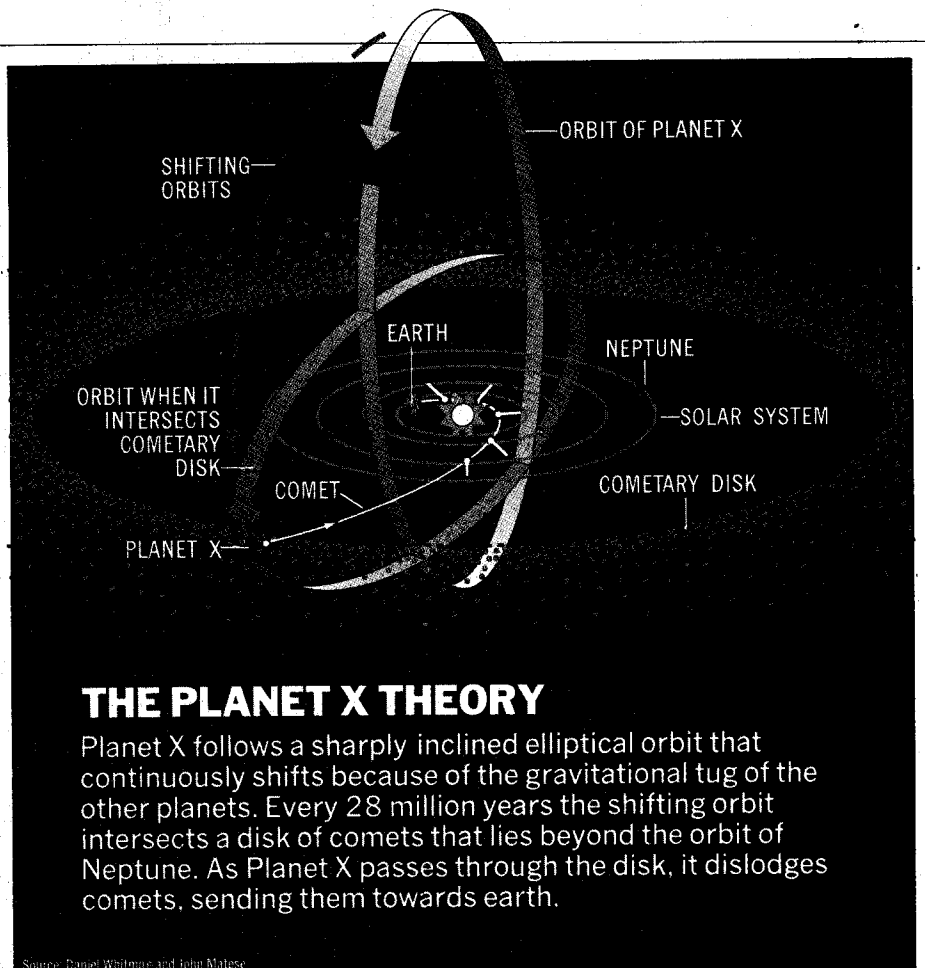
RESSEMER-WHEELER PICTURES

horse on a merry-go-round." Significantly, the sun and its accompanying planets hit the dustiest sections once every 33 million years or so, a figure that does not quite jibe with the apparent extinction cycle of 26 million years but is at least within the margins of astronomical and geological error.

Sniffing a connection, Rampino and a Goddard colleague, Astrophysicist Richard Stothers, among others, proposed an ingenious way that the oscillating journey might trigger bombardments on earth. Whenever the sun passes through the Milky Way plane, they suggested, the swirls of dust it encounters would gravitationally disrupt the Oort cloud, a vast bubble of comets that scientists believe surrounds the solar system at a distance of up to 10 trillion miles from the sun. Like a lazy fruit picker shaking plums from a tree, the dust would send showers of comets falling toward the sun. Some comets would collide with the planets, including the earth. Almost immediately, other scientists began tearing the Rampino-Stothers model apart. First of all, they said, the sun is pretty close to the middle of the galactic plane right now, and yet there has been no major extinction occurrence for millions of years (the last one apparently took place 11 million years ago, wiping out some marine protozoans and mollusks). More damning still, Physicist Patrick Thaddeus, also of Goddard, pointed out that dust clouds are so widely distributed that the Oort cloud should be encountering them practically all the time, not just once every 33 million years; some of the numbers his colleagues used in their calculations, he says flatly, are "just the wrong numbers."

Among the various astronomers who considered and promptly rejected the galactic carousel notion was California's Muller, a scientist obsessed by periodicity. If a familiar cosmic mechanism could not account for the cyclic nature of extinctions, he decided, something completely different would have to do. During Christmas break in 1983, Muller and fellow Astronomers Marc Davis of Berkeley and Piet Hut of the Institute for Advanced Study in Princeton were brainstorming about stars and periodicity, when Muller noted that more than half the stars in the galaxy are thought to be binaries (pairs of stars that orbit a common center of gravity). Suppose the sun has a companion, he mused, and that companion was somehow disrupting the solar system's asteroid belt. Trouble was, he conceded, he could not come up with a convincing orbit for the companion. Suddenly the Dutch-born Hut interrupted him with an alternative suggestion: Why not make the companion star travel through the thickest part of the comet-filled Oort cloud, rather than the asteroid belt? Muller immediately saw that the problems he had had with asteroids disappeared when he substituted comets as the culprits. As he recalls, "We wrote the first draft of our paper that day."

The three realized that the sun's coun-



THE PLANET X THEORY

Planet X follows a sharply inclined elliptical orbit that continuously shifts because of the gravitational tug of the other planets. Every 28 million years the shifting orbit intersects a disk of comets that lies beyond the orbit of Neptune. As Planet X passes through the disk, it dislodges comets, sending them towards earth.

Source: Daniel Whitmire and John Matese



CHRISTOPHER R. HARRIS

John Matese and Daniel Whitmire plotting the probable orbit of the mysterious Planet X

To loose the rain of comets and justify the meanderings of Uranus.

terpart, if it existed, would have to be like no other companion star ever identified; it would travel in an enormous elliptical orbit three light-years across that would periodically take it farther from the sun than the distance between any known binary stars. Because it has not been identified in the four centuries since astronomers began using telescopes, it must be very small and dim, perhaps a red dwarf with one-third the mass and only one one-thousandth the brilliance of the sun. When it passed

through the Oort cloud, it would dislodge a billion or more comets. Muller, searching for an appropriate name for the lethal companion, considered several. But the one that stuck was Nemesis, the Greek goddess who punishes the proud.

Before publishing their report, Muller decided to get a second opinion from the fathers of the impact theory, Luis and Walter Alvarez. Neither conferred his benediction on the hypothetical star, but Walter recommended one way that its

existence might be tested. He knew that if comets cyclically pelted the planet, they must have left behind craters in chronologically distinct batches. Water, wind and continental drift have eroded most of the earth's impact craters, but 100 of the largest survive in some form and have been roughly dated. Muller and Walter Alvarez examined the data on 13 of the best-dated craters spanning a period of 250 million years and, sure enough, the gutting seemed to occur in peaks of 28.4 million years (although the later inclusion of data from other craters made the pattern seem less conclusive).

The results of the crater analysis were published in the British journal *Nature*, right beside the Nemesis report. Coincidentally, that same issue contained yet another paper on the death star. It was from Whitmire, who had independently conceived of a companion to the sun.

Reviews for the Nemesis debut were what might be called mixed. Critics charged that so gigantic an orbit had never been recorded for two companion stars, and with good reason. If the sun and its presumed partner were actually three light-years (18 trillion miles) apart, they said, the gravitational attraction between them would be so feeble that a passing star or dust cloud would have bumped Nemesis out of orbit long ago, certainly before it could come back through the Oort cloud a dozen times. Says Shoemaker, who has been something of an impartial judge in the periodicity controversy: "I give this idea less than a 1% chance of being correct."

The warrior star, however, has captured the imagination of many others. Says Tom Gehrels, an astronomer with the University of Arizona: "When I heard the theory, I knew in my heart it was right." Indeed, Gehrels immediately hopped on a westbound plane to try to persuade Muller to let him help search for the companion. But Muller's own telescopic dissection of 5,000 stars in the Northern Hemisphere that are candidates for being Nemesis was already under way, and there was no need for Gehrels' help. So far, Muller has photographed nearly all the target stars once and is preparing to shoot them again in an attempt to detect some telltale movement.

Offers of assistance have come from other quarters as well. Jordin Kare, a physicist with Lawrence Berkeley Laboratory, has suggested that a 24-in. Schmidt telescope in Australia be used with a computer scanning system called the Star Cruncher to survey the Southern Hemisphere skies. If these approaches turn up a blank, Kare and Muller will launch a Star Cruncher search in the north. And at JPL, Astrophysicist Thomas Chester, chief of the I.R.A.S. data team, is sifting through recorded I.R.A.S. transmissions looking for Nemesis and other unusual objects. Although I.R.A.S. operated for only ten months in 1983 before dying, it managed to chug out data on



William Clemens and a cast skull of a victim of extinction: Tyrannosaurus

Why should the mammals have survived any Cretaceous catastrophe?

250,000 cosmic objects, which scientists have just begun to analyze. Chester is hunting for cool stars that may have suspiciously shifted. To date he has identified 5,000 likely objects and narrowed the list to 15, which he plans to photograph half a year apart to check further if they are candidates for the star role of Nemesis. Says Muller: "I figure all these searches could take about two years."

Early this year, another scientist joined the Nemesis hunting party. Armand Delsemme, a Belgian-born astrophysicist at the University of Toledo in Ohio, announced that he had just about zeroed in on the best place for Muller or Chester to look for the death star. He has plotted the paths of 126 comets and discovered to his great surprise that they journey around the sun in oddly skewed orbits. Some very powerful object must be out there gravitationally directing the flow of traffic, he says, and that object could be Nemesis.

Although Louisiana Astrophysicist Whitmire does not dismiss the death star theory, he thinks that his Planet X theory of periodic comet showers has greater potential. For one thing, a still undiscovered planet has a distinct advantage over Nemesis as a promising candidate because astronomers have been predicting its existence since the late 19th century, first as the ninth planet and then as the tenth. Reason: its existence and gravitational pull might explain discrepancies in the movements of Neptune and Uranus. Even the discovery of Pluto in 1930 did not fulfill the gravitational force needed to justify Uranus' meanderings, and some astronomers have long thought that a tenth planet is somewhere out there. Astronomer Robert Harrington of the U.S. Naval Observatory has gone so far as to paint a description of the suspect, and it is no pedestrian planet. It is three to five times the mass of the earth, is gaseous like Jupiter, has an orbit that is ellip-

tical rather than circular and inclines to the plane of the solar system at an angle of perhaps 30° or more; its year (the time it takes to orbit the sun once) is 800 to 1,000 earth years long. To have been influential in shaping the current orbit of Uranus, he thinks, it made its closest approach to that planet in the 1700s.

In devising their Planet X model, Whitmire and fellow Louisiana Astrophysicist John Matese took an entirely different tack, determining the nature and orbit of a planet that would loose rains of comets at the necessary intervals. The result of their calculations: a planet with an orbital plane that slowly rotates around the sun, completing its cycle once every 56 million years. Twice during that cycle, every 28 million years, Planet X's orbit carries it through a disk of comets lying just beyond Neptune, dislodging many of them.

To meet all the other requirements imposed on it by the Louisiana scientists, Planet X would have an orbit that is elongated and highly inclined and a mass one to five times that of the earth. In other words, their Planet X is remarkably similar to the one that could account for the irregularities in the orbit of Uranus. The beauty of the theory, in Whitmire's view, is that it relies on a planet originally proposed for reasons that have nothing to do with mass extinctions. Still, he admits, the proof of the pudding "is going to come in the observing."

Most scientists are waiting for that pudding to be served before they commit themselves to the idea of periodicity, let alone a particular model. Says Cornell Astronomer Carl Sagan: "None of the explanations is anything like fully satisfying." Yet all but a few diehards acknowledge the brilliance of the Alvarez work. They believe the iridium layer and subsequent discoveries indicate that impacts of extraterrestrial objects may have played a

CAROL A. FOOTE

significant role in certain extinctions, either directly or by delivering a final coup de grace to species already debilitated by climatic changes.

Whether these catastrophic impacts are random or cyclic remains to be seen. But if they occur at all, they could shake the foundations of evolutionary biology and call into question the current concept of natural selection. Should the Alvarez theory be correct, says Harvard Paleontologist Stephen Jay Gould, the importance of competition between species diminishes. If every so often a megablast opens up a broad array of ecological niches, then new creatures can flourish without having to crowd out the old. "If you ask the ques-

tion, 'Why are we here?'" says Gould, "the answer is, 'Because the dinosaurs disappeared, not because the mammals out-competed them.'"

Astronomers probing the skies for signs of extraterrestrial intelligence can take heart from the new catastrophe theories as well. For example, the double-star systems that make up the majority of stars in the galaxy were long thought to be too unstable to support planets that could settle into regular orbits and give rise to life. But if the sun is part of a celestial duet, says Raup, then "the whole evolutionary process may thrive on this kind of disturbance."

Or could it be that the permutations of

life on earth are governed not by comets or death stars but by something more old-fashioned—like the fates? Although Shoemaker and Walter Alvarez do not consider themselves superstitious, they recently found reason to rethink their beliefs. During a visit to Berkeley, Shoemaker had roundly blasted the Nemesis idea, so Alvarez took him to a Chinese restaurant for a further discussion of Muller's model. After dinner, Alvarez cracked open his fortune cookie, pulled out the paper strip, glanced at it and, suppressing a laugh, handed it to Shoemaker. It read: "The star of riches is shining on you."

—By Natalie Angier. Reported by Robert Buderl/Berkeley and Christine Gorman/New York, with other bureaus

Cretaceous Fairy Tales

In one episode of the classic Walt Disney film *Fantasia*, the dinosaurs take over the earth to the impassioned strains of Stravinsky's *Rite of Spring*. An adorable clutch of baby triceratopses hatches from eggs; sloe-eyed brontosaurus wade in marshes; a bony-backed stegosaurus struggles for its life against the meat-eating *Tyrannosaurus rex*. But as the years flash by, the world mysteriously grows hotter and more violent: swamps evaporate, earthquakes trigger giant tidal waves, and the princely reptiles crawl across an encroaching desert to meet their certain doom.

Disney's celluloid fantasy is scarcely more elaborate than some of the theories that researchers have concocted to explain the demise of the dinosaurs at the end of the Cretaceous period, 65 million years ago. Some of the more notable flights of fancy, while capturing the public's imagination, have strained scientists' credulity. Yet, complains Physicist Richard Muller, "these are the theories kids are taught by their elementary school teachers."

Perhaps the most popular of these Cretaceous creations deals with eggs. It holds that small mammals appearing during the first half of the dinosaurs' reign stole and ate all the reptiles' eggs, the dinosaurs could not fight back effectively because the warm-blooded thieves were too fast and could easily dash into crevices for protection. This theory might account for the fact that so few fossilized dinosaur eggs have been found, but it does not explain how the dinosaurs were then able to coexist with mammals for so long a time—more than 100 million years.

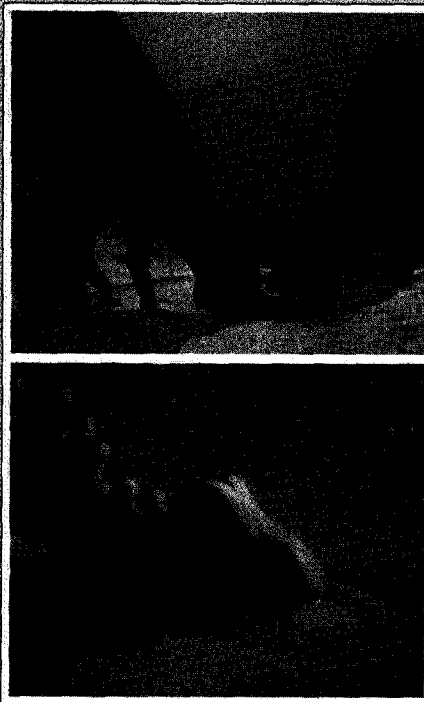
One hoary belief involves dinosaur stupidity: the hapless creatures died out because their bodies continued to grow bigger while their brains remained small. Indeed, cranium measurements seem to indicate that at least some species were not terribly cerebral: one type of brontosaurus, for example, weighed about 30 tons, and probably had only a half-pound brain. If the dinosaurs did indeed become progressively less intelligent, the theory goes, they would have lost the ability to adapt to changes in the environment.

Even those dinosaurs known to have proportionately larger brains like tyrannosaurus may have simply been too massive to survive on land. How could their bulk have been lethal? According to one suggestion that many weekend athletes can identify with, the dinosaurs suffered from slipped disks, which left them unable to forage for food. Great heft could even trigger infertility. In 1946 a paleontologist concluded that because large animals do not shed excess heat as efficiently as small animals do, a temperature increase of just 2° F could have baked the considerable testicles of a ten-ton male dinosaur enough to kill his sperm.

If the size of some dinosaurs did not do the trick, maybe their culinary habits did. They could have been fussy eaters, for example. "If they ate mainly one plant, just as the koala bear lives on eucalyptus," says James Hopson, a dinosaur expert at the University of Chicago, "they would be in trouble if that plant were no longer available."

Or maybe dinosaurs were not picky enough. Perhaps they died from indiscriminately eating poisonous plants. Ronald K. Siegel, a psychopharmacologist at the UCLA school of medicine, points out that alkaloid-producing angiosperms began evolving toward the end of the dinosaur era. These plants produce toxic chemicals, but they also taste so bitter that most modern creatures know to eschew rather than chew them. If the dinosaurs lacked a palate, however, some of them may have died on an overdose of the poisons. Others have suggested that because the angiosperms replaced ferns, a possible dinosaur dietary staple containing laxative oils, the reptiles may have been the first creatures to succumb to constipation.

Unlike theories about catastrophic impacts, or changing climates and sea levels, these fanciful concepts all fail to account for the hundreds of other species that perished at the end of the Cretaceous. Says Physicist Luis Alvarez of the University of California, Berkeley: "The problem is not what killed the dinosaurs but what killed almost all the life at the time." Muller believes that comets are a far more plausible explanation for the death of the dinosaurs, but he wryly allows one other possibility. Says he: "Maybe there just wasn't enough room for them on the ark."



Fantasia's demise of the dinosaurs

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