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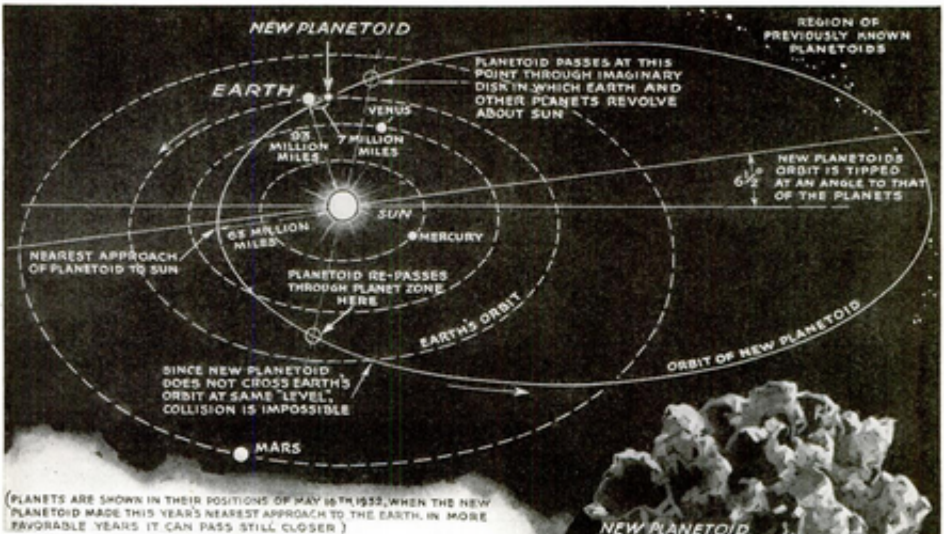
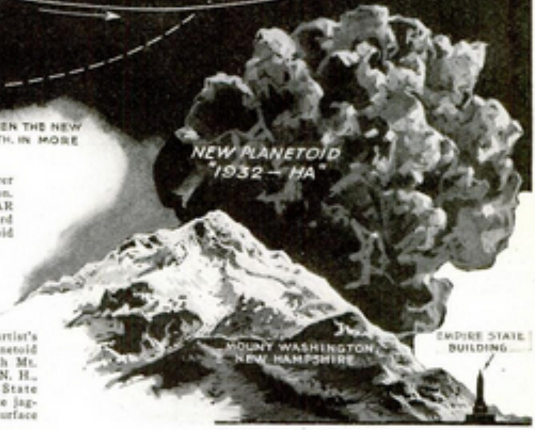
New Baby Planet Is Close to Earth



Map shows that the newly discovered baby planet swings nearer the earth than any other heavenly body except our own moon. The map is based upon a sketch drawn especially for POPULAR SCIENCE MONTHLY by Dr. Fred L. Whipple of the Harvard Observatory, who was the first in America to see the planetoid



Here is our artist's idea of the planetoid compared with Mt. Washington, N. H., and Empire State Building. Note jagged nature of surface

FOR untold years, the earth has had a neighbor up in the sky and no one ever knew it! A chunk of rock two or three miles in diameter, tiny in size but important enough to be designated officially as a "planetoid" or baby planet, has just been discovered and identified as the nearest thing to us, except our own moon, in the whole solar system. The find is hailed as the most spectacular event in astronomy since the discovery of the major planet Pluto two years ago.

At its nearest approach to the earth, astronomers have figured, the new planetoid is only ten times as far away as our moon. Standing upon it, a man with a pair of field glasses could obtain a good view of the earth, and plainly see its continents. Danger of a collision between it and the earth is averted only through the fortunate circumstance that its orbit is tilted with respect to ours, and the two points where it crosses our "level" are respectively inside and outside the earth's path.

Because the tiny world is one of the smallest in the solar family, it is invisible to the naked eye. Under extremely favorable conditions it could be observed with a six-inch telescope as a faint, starlike pin point of light. The name "1932-HA" has been assigned to it pending selection of a more euphonious title, the number indicating the year of discovery and the letters its code name, in accordance with astronomical custom.

A German astronomer, Dr. Karl Reinmuth of the Heidelberg Observatory, discovered the baby planet a few weeks ago. When he announced the find, American observatories picked up 1932-HA and confirmed its existence. First in this country to see it were Dr. Fred L. Whipple and his assistant, L. E. Cunningham, using the six-teen-inch refracting telescope of Harvard Observatory at Cambridge, Mass.

Picture a jagged fragment of rock, more likely irregular than round, about the size of Mount Washington, New Hampshire, and you will have a good mental image of 1932-HA, Dr. Whipple told POPULAR SCIENCE MONTHLY. Its surface, evidently rough since it reflects light but poorly, probably is covered with great masses of crags. A human being visiting 1932-HA would find no air to breathe, and violent extremes of temperature would alternately scorch and freeze him. Even if he could surmount these difficulties, he must move with the greatest caution. So weak is 1932-HA's force of gravity, Dr. Whipple points out, that if this imaginary visitor were to take a strong leap, he would bound clear off the planetoid, never to return!

Our sky neighbor travels in a great ellipse 280 million miles long, requiring a little more than twenty-one months to complete the round trip, Dr. Whipple's calculations show. The journey takes it within 63,000,000 miles of the sun — nearer even than Venus. In some years it goes by the earth more closely than in others. Last May it passed us at a distance of seven million miles, but under favorable circumstances it might approach within two and a half million miles—the distance the earth travels in three days in its journey around the sun.

Along the outer rim of its orbit, 1932-HA visits the region filled with the previously discovered planetoids, or asteroids, as they are sometimes called. More than a thousand are known, ranging in diameter from a few to several hundred miles, but virtually all travel in a well-defined cluster between the orbits of Mars and Jupiter. Only a few, such as Eros, cross the Martian boundary line. The new planetoid is the first of its family known to pass within the earth's orbit, and its discovery brings the center of astronomical interest back to our doorstep just when most new discoveries of heavenly wonders were being made at remote regions of the universe.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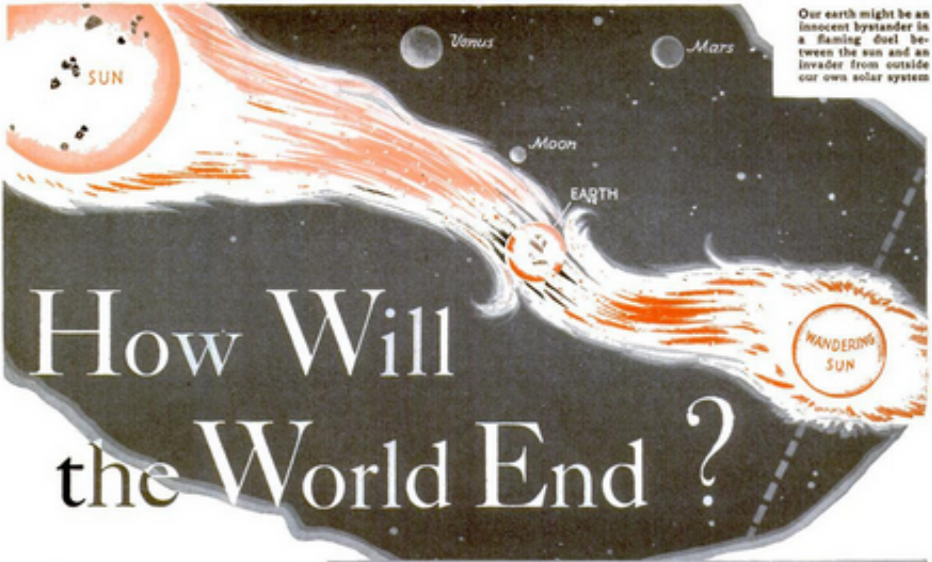


Our earth might be an innocent bystander in a flaming duel between the sun and an invader from outside our own solar system

How Will the World End?

FOR many millions of years, our planet has circled its parent sun on a time schedule so accurate that it varies only a fraction of a second in each century. The earth is always "on time" throughout every round trip.

Yet, it is quite possible that this regular and peaceful schedule may some day be interrupted by an unforeseen event, which, if it *does* occur, will probably bring humanity's greatest and perhaps final, catastrophe! By means of simple experiments, you can study the possible ways in which our planet's doom might come, and show the forces which may some day bring ruthless destruction upon a helpless world.

Strangely, the way which offers the greatest menace to the earth is exactly the way in which the earth itself came into being! It is now generally believed that the material which later condensed into the planets of our solar system was drawn out of the sun in huge tidal streamers, raised by the close passage of another, a wandering sun.

This passage may have been almost a grazing collision, for two great, flaming cigars of incandescent matter, millions of miles long, were lifted by the huge tidal forces out of our sun.

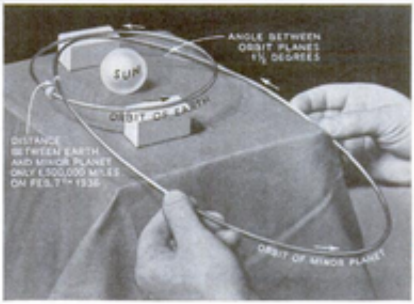
Later, when the invader receded, and the duel of gravitational forces subsided, the flaming streamers were left circling around the suns which had torn them loose in their titanic tug of war.

Gradually, through condensation and a "sweeping up" of little masses by bigger ones, the planets of our solar system were formed out of the floating streamers of our sun. Of the offspring, one, at least, produced conditions which brought about life as we know it.

What happened to the other sun and its circling planet material we do not know. It may still be visible through powerful telescopes, as one of those faint stars which the "red shift" of the spectroscope tells us are receding steadily from our solar system. (P. S. M., June '34, p. 103.) We have no means of knowing where to look for this wanderer, for we do not know in which direction it left us.

And that is exactly the uncertain state of affairs with regard to a possible invasion of our peace by another wandering sun. We do not know which way to look for its possible approach. Any one of those distant suns which our spectroscopes say are coming our way may keep on coming —*straight for us!* We have no way of knowing.

Some astronomers tell us that close approaches and grazing passages of suns are

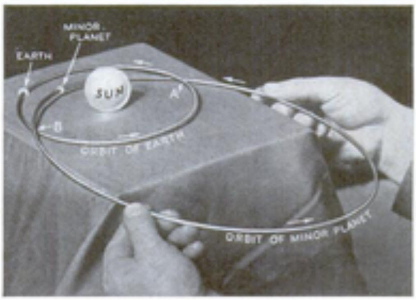


PLANETS MEET AT AN "OVERPASS"

Like an auto shooting across a parkway on a bridge, a baby planet whizzed past the orbit of the earth only a few months ago. It missed our world by a scant 1,500,000 miles

WILL THERE BE A CROSSING CRASH?

A relatively slight alteration in the orbit of the minor planet, as illustrated in the experiment shown here, would make it intersect the path of the earth as at the two points A and B



very rare indeed. Others think them more frequent. But this much is certain: what has happened may happen again—and if another wandering star should travel in our direction, we would be in for such trouble as the earth has never known in all its countless hundreds of years.

Our first warning might come when some observer of variable stars noticed that a particular dot of light showed a steadily increasing brightness. Then, as the brilliancy of the oncoming sun continued to grow, its path would become the principal subject of study for all the astronomers on earth. They would have plenty of time to plot its course, for even at the enormous speeds with which stars travel, it would require many years, perhaps centuries, for the approaching destroyer to come close enough to influence the movements of our solar system.

The first "perturbations" caused by the tidal pull of the invader would of course affect our outermost planets, Pluto and Neptune, provided that they happened to be in the parts of their orbits that lay in the oncoming sun's road. If so, these planets would soon move more slowly; they would no longer fulfill the time schedule which astronomers have laboriously determined from their movements.

And then, as the visitor's influence over our system grew, steadily and relentlessly, we should observe that our greatest planets, Saturn and Jupiter, were no longer "running on time."

By this time, daily and hourly bulletins from the world's observatories would be front-page news all over the world. As the doom of our sun's family, and, therefore, that of the earth, became more and more inevitable, we should see startling changes in human affairs.

And then astronomers would find that our neighbor Mars and the earth itself were obeying the attraction of the invading star as much as that of their own sun.

IF A PLANETOID SHOULD COLLIDE WITH THE EARTH

Here our artist imagines the scene that would be enacted if a minor planet like our recent visitor, Anteros, should strike the earth at the National Capitol in Washington, D. C. A mass of metal, a mile or two in diameter, hurtling through the air at a terrific speed and white-hot from friction with the air, would spread destruction over a huge portion of our globe

By GAYLORD JOHNSON

The inclination of our polar axis might change, making navigation by the sun and stars uncertain, perilous, or entirely impossible. Nothing, in fact, would remain normal except the rotation of the earth on its axis.

The whole world's climate would become fiercely torrid, due to the hot rays of two suns instead of one. In a blaze of continuous, merciless sunlight, even night and day might cease to exist. And, finally, the great tidal streamers of flame from the two fiercely contending suns would vaporize all the planets, including our own, as drops of water disappear on a hot stove.

But this would occur to a world already bereft of life, for, long before the final cataclysm, we should have lost consciousness in the scorching atmosphere, and fields, streams, and seas would have dried up and vanished, in smoke and steam!

The size of the flaming prominences which would be raised out of both suns by their near approach can be imagined from a glance at the actual photograph of a solar prominence, which was raised merely by the sun's internal forces. It looks filmy and small in the photograph, but it is over a quarter of a million miles high—more than twice the distance from our earth to the moon! It is quite conceivable that close approach of the visitor might pull out flaming projections far enough to vaporize our earth, for it must be remembered that all our planets were formed from such a streamer of matter, and that Pluto, the farthermost one, is now 4,650,000,000 miles from our present sun. The original streamer must have been a long one!

So much for this possibility of world catastrophe. We must now leave it, and investigate briefly the other way in which the end of our earth might come to pass.

In this case, the destroyer would not be an intruder from outside, but a member of the sun's own family—one of the several hundred minor planets, or "planetoids," most of which revolve around the sun in orbits between the paths of Mars and Jupiter. That they do not all do so has been known to astronomers for a long time, and has been startlingly proved within the past few months.

In fact, only a few months ago a minor planet actually (Continued on page 123)

EASY EXPERIMENTS GIVE YOU A PREVIEW OF THE DESTRUCTION OF OUR EARTH BY FLAMING SUNS OR RUNAWAY BABY PLANETS

EARTH VERSUS PLANET

This test with a magnet and a steel ball shows how the earth's attraction might deflect a planetoid from its orbit. At right, pictograph of the sun shows fiery rockets that may destroy the earth

THE END OF THE WORLD

(Continued from page 53)

crossed the path of the earth (P.S.M., May'36, p.17), missing us by only a scant 1,500,000 miles—a mere nothing, as astronomical distances go.

The approach of this undiscovered, unknown planetoid was not detected, because it came from the direction of the dazzling sun. It was only after its passage outside our orbit that it was discovered, and its path plotted by astronomers.

It is the close approach which the road of this wild planetoid makes to the orbit of the earth that has caused astronomers to speculate a little anxiously about expected return trips in the future. The plane of its orbit slants only about one and a half degrees to the plane of the earth's orbit, which it crosses twice in each revolution.

THIS minor planet's "year," or the period of its revolution around the sun, is equal to two and one half of our years. Where will the earth be in its course at the time of the next return of the erratic midget world? And the next, and the next?

At their close passage last February, the earth and the planetoid were somewhat like two automobiles—one passing along a parkway, the other shooting across it by an overpass bridge.

Astronomers are now wondering whether, at some succeeding passage across the earth's orbit, the safe overpass may possibly become a perilous grade crossing! If it ever does, and the two planets arrive there together, there may be no one left on earth to tell the story. At the least, there would be nation-wide destruction in some part of the world!

The model, made of stiff wire and photographed in two positions, shows how slight a change in the slants of the two orbits might set the stage for earth's greatest catastrophe.

It is even conceivable that the recent close passage of the planetoid above the earth may have already deflected it nearer to the earth's orbit plane. The experiment illustrated, with a magnet and a ball bearing, shows how this deflection might be caused by the earth's strong attraction for the much smaller planetoid.

That huge meteors, or, possibly, minor planets, have struck the earth in the past is shown by the enormous craters left at a few points on the earth's surface. The best-known example is in Arizona, and was produced at an unknown time in the past. Another such collision, caused either by a giant meteor or a small asteroid, occurred during 1909 in Siberia. The impact apparently vaporized the projectile in a great explosion, which blew down and burned a forest of large trees for a distance of fifty miles in every direction!

ALTHOUGH the chances are extremely small that return of the minor planet would coincide exactly with the presence of the earth at one of the points where its path crosses ours, still, the future activities of the unexpected visitor will be keenly watched. Its unseen approach makes us wonder how many more of its kind are running amuck across the solar system. Even now, we may actually be approaching another perilous grade crossing!

SPARK REVEALS ELEMENTS IN BLOOD STREAM

Elements present in the human blood stream in quantities as small as one part in 100,000 are detected by a method recently perfected by Michigan scientists. A 25,000-volt spark jumps across a gap between two electrodes containing samples of the blood being analyzed, and the flash of light is broken up by a spectroscope. By examining the color lines, experts can determine exactly what elements are present in the sample.

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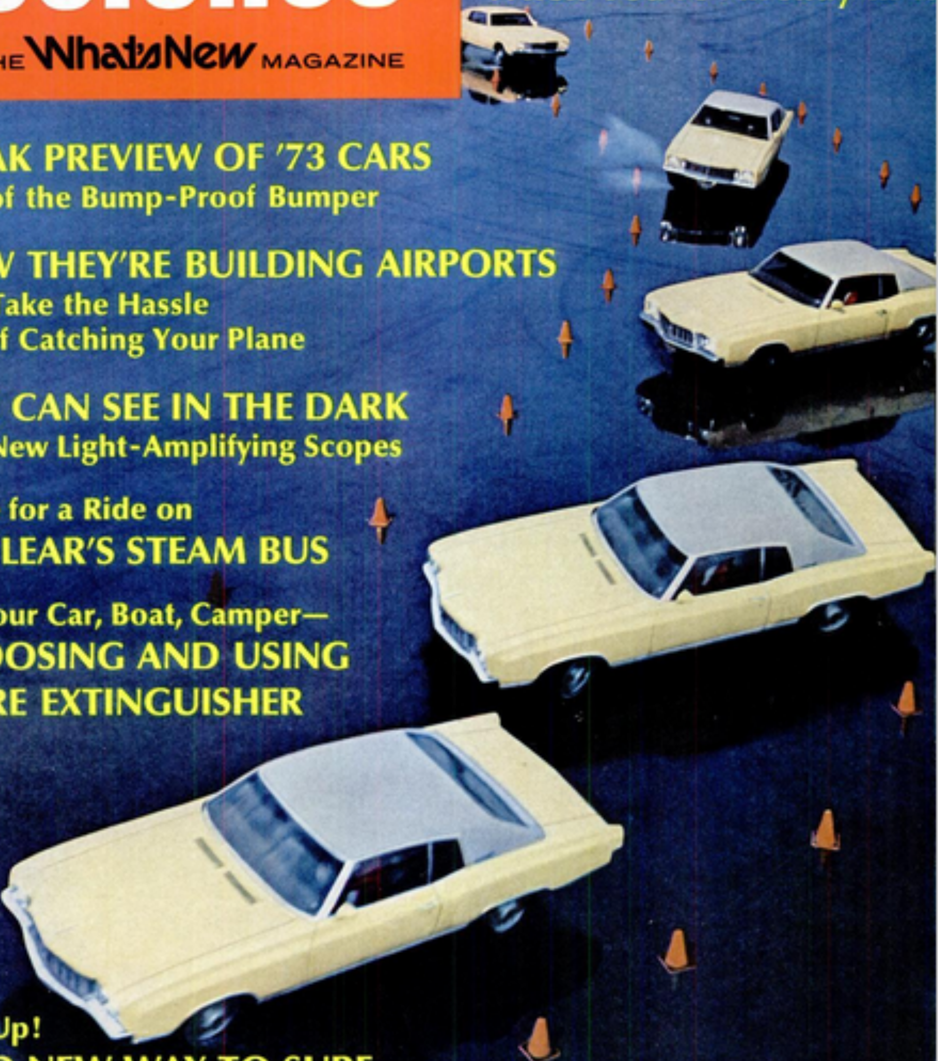

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The buoy is an 11-foot-long horizontal steel cylinder with a four-foot keel at one end to provide stability in high winds and rough water. It will be moored in water as deep as 24,000 feet, and will measure air temperature and pressure, wind speed and direction, water pressure 200 meters down, and water temperature at depths between two and 200 meters.

Tenth planet found?

One sure path to astronomical immortality has been to discover a planet. After all, there are only nine of them orbiting the sun. Or are there? Since the discovery of the ninth planet, Pluto, 42 years ago, some astronomers have insistently postulated the existence of an even more remote tenth planet—Planet X. Now Joseph L. Brady, a scientist at the Lawrence Livermore Laboratory of the U. of California, says that he may have found Planet X—not visually or photographically, but by inference and computer analysis.

How? Brady examined the course of Halley's Comet, a periodic visitor to the solar system whose behavior is marked by peculiar irregularities. They seemed to be accounted for by the presence of a distant planet's gravitational pull.

Computer analysis showed Brady that the eccentric behavior of Halley's Comet could indeed be explained by a Planet X—but only by one with its own peculiar profile. It would have to be almost six billion miles from the sun, three times bigger than Saturn, and with a retrograde motion. Confirmation of Brady's theory will come when—and if—someone photographs Planet X.

A tooth-shaking event

This looks like a fiendish torture device, but it isn't. It's a tooth-shaking machine, and Dr. David H. Noyes (left), an assistant professor of physiology at Ohio State U., is attaching it to the teeth of technical assistant Wilbur Reed, who should probably go down in history alongside the yellow-fever volunteers. In use, a cylinder cemented to a tooth vibrates at various frequencies. The machine measures the force (not more than a tenth of an ounce) and the tooth's response (average movement is about one ten-thousandth of an inch). The subject can listen to music over headphones to overcome acute anxiety.

Actually, the process is painless, and the purpose noble: to develop means of detecting the onset of bone and gum disease—periodontal disease—before permanent damage occurs. The disease is the largest cause of tooth loss for people over 30 years old. The mobility of a tooth may be an important index of the condition of its supporting structures.

Flood-warning system

One hundred fifty-three people drowned in flash floods when a last-gasping Hurricane Camille unloaded 27 inches of rain in eight hours on the James River Basin of Virginia, in August 1969. To prevent the recurrence of another such catastrophe, the National Weather Service is activating the first of a new series of warning systems that will automatically set off an alarm when a flash flood threatens. Installed near Wheeling, W. Va., the system consists of a robot water-level sensor (incorporating a toilet-tank-type float device) at an upstream point on the river, an electric power supply several miles or more downstream, and an alarm that will flash, buzz, or otherwise signal a town in danger.

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DEATH STAR

At various times in the remote past many forms of life on Earth perished relatively suddenly. The extinction of the dinosaurs 65 million years ago is the most notorious of these events. Why did it happen? A bold and highly controversial new theory holds that our sun is not a solitary wanderer in the galaxy but has a companion star, dubbed Nemesis, that visits the solar system every 26 million years and unleashes a deadly fusillade of comets. The result: the periodic mass extinction of life on Earth.

Prelude to extinction: Evidence abounds that 65 million years ago the catastrophic event illustrated here could have resulted in the extinction of 50 to 75 percent of all species of life on Earth. The painting at left shows a cometary body or asteroid, about six miles across, plummeting through Earth's atmosphere. Frictional heating produces a long tail of debris. In the painting below, which is based on experiments with actual impacts and explosions, a conical sheet of ejected matter spews from the impact site 60 sec. after the collision. Within minutes after the collision, according to computer simulations, the atmosphere would be freighted with dust particles and water vapor, blocking sunlight for months and thus generating violent alterations in climate and photosynthesis. The result would be mass extinction. Both views are from an altitude of 62 miles.

By ARTHUR FISHER

Maybe we didn't see it at first because we didn't believe it was there."

David Raup, a noted paleontologist who is chairman of the geophysics department at the University of Chicago, was describing what he and his colleague, John J. Sepkoski Jr., finally *did* see. Although it had been known that mass extinctions occurred more than once in remote times, Raup discovered what appeared to be a startling pattern: a regular, periodic occurrence of mass death every 26 million years over the last 250 million years.

The observation was dismissed by many scientists because there seemed to be no way to explain it. No known geological or biological cycle operates on such a vast time scale. But it could possibly fit with another clue. Several years ago, physicist Luis Alvarez discovered evidence that a large body from space—an asteroid or comet—hit Earth at about the same time the dinosaurs vanished. Putting together Raup's evidence—that mass extinctions have happened regularly—with Alvarez's work suggested a startling new idea. Could Earth have been bombarded with comets once every 26 million years? And if so, what could possibly have launched them? The question set off a spate of almost frantic speculations by astronomers and astrophysicists.

Now one of the boldest of their theories is being tested. It holds that every 26 to 28 million years, Earth is showered with a deadly hail of comets, dislodged from their normal abode on the outskirts of the solar system by the periodic encounter with a dim, dwarf companion star to our sun. This star, named Nemesis by the astronomers who conceived it, is now being sought. If it is found, the discovery will force a radical change in our notions of the evolution of life, Earth, and the solar system, a change even more profound than the reluctant acceptance of the once-scorned theory of continental drift.

The rapid emergence of this stunning theory dramatically illustrates how science works. It resulted from the restless exchange of ideas among scientists from very different disciplines—paleontologists, physicists, geologists, nuclear chemists, astronomers—with theories melting or hardening in the fires of debate.

The theories and the debate have a long history. The subject of the great dyings was as fascinating to our ancestors as it is to us. Charles Darwin, pondering the disappearance of many large mammals from the pampas of South America, wrote: "Certainly no fact in the world is as startling as the wide and repeated exterminations of its inhabitants." Raup adds a modern observation: "The extinction of individual species," he says, "has been considered a normal part of evolution." But at least six times in the last half-billion years of Earth's history, extinctions have "gone off the scale," with the simultaneous disappearance of many families of living things.

What Raup calls the two "biggies" of the mass extinctions occurred about 225 million years ago and 65 million years ago. The more recent one came at the boundary between two geologic periods called the Cretaceous and the Tertiary, so researchers refer to this event as the C-T boundary extinction. It is the most notorious because it is the one that killed the dinosaurs—plus an estimated 50 to 75 percent of all animal species.

How to account for such mass dyings? The debate began late in the 18th century, when workers excavating a site in the Montmartre district of Paris turned up strange fossils, which they gave to the noted French naturalist Georges Cuvier. He and others found that the dug-up earth revealed a succession of markedly different layers, each bearing a different fossil imprint, many with no living counterpart. In some layers there were no fossils at all. Cuvier concluded that the abrupt changes in the sequence of geological formations and the record of life they bore must have been caused by a series of "frightful occurrences" that periodically smote Earth, altering its face and wiping out life on a large scale.

This view, called catastrophism, was opposed by a different camp of naturalists, geologists, and philosophers who held for the theory of *gradualism*. The record of past life and geological change, they insisted, could be explained solely on the basis of gradual changes occurring over immense periods of time.

The debate has continued into our time, with many experts subscribing to a kind of blend of the two approaches: gradual changes over long periods of time, but punctuated by occasional catastrophic events. For example, geologist Dewey McLean of Virginia Tech believes that 65 million years ago, Earth underwent a period of rampant volcanism, throwing large amounts of carbon dioxide into the atmosphere, initiating a greenhouse scenario that warmed the planet gradually, slowly altering the dinosaurs' reproductive abilities so that they gradually died out after about two million years.

On the other hand, catastrophists have hypothesized supernovae bursts (with a swarm of thermal neutrons bathing Earth, according to one recent theory); magnetic reversals; outbreaks of frigid Arctic Ocean water; lunar volcanoes; and impacts with foreign bodies.

A striking new theory

Whatever the merits of these various ideas, the tenor of the mass-extinction debate changed forever in January 1980, with an announcement by Nobel Prize-winning physicist Luis Alvarez. He said that he and colleagues at the University of California's Lawrence Berkeley Laboratory had definitive evidence that a large extraterrestrial body—probably an asteroid six miles across—had struck Earth 65 million years ago. He said he knew an asteroid struck because it left a chemical calling card. Frank Asaro and Helen Michel had found an extremely high concentration of the rare element iridium in layers of rock at the C-T boundary layer, and the element was not of earthly origin. Furthermore, it coincided precisely with the fossil record of the mass extinction. The impact, Alvarez proposed, threw up a vast cloud of dust and debris that shrouded Earth from sunlight long enough to interrupt most photosynthesis and wreak climatic havoc, thereby wiping out many life forms [PS, Feb. '83].

That claim, made five years ago, was greeted with great skepticism. Controversy still flourishes over the biological aspects of Alvarez's theory. But since the time Luis's geologist son, Walter, found the first evidence in a thin fossil-free strip of reddish-brown clay near Gubbio in central Italy, geological sampling has dug up at least 75 more instances of the iridium tracer at sites—all over the world—that can be dated as coinciding with the C-T extinctions. Added confirmation comes from the discovery of abnormally abundant amounts of such other elements as osmium—normally rare on Earth's surface—at various C-T boundary-layer sites.

What about the crater that the asteroid impact must have formed? None has been found that fits the theory. One explanation: The asteroid might have hit in the sea. Another possibility: Tectonic activity could have subducted the plate bearing the crater under an adjacent one.

Now, however, there is physical evidence of an actual impact, even absent a crater. At a Lunar and Planetary Science meeting last year in Houston, Bruce Bohor and colleagues from the U.S. Geological Survey in Denver re-

Continued

ported that they had analyzed an iridium-rich C-T boundary-layer clay from Montana. They found quartz particles with crystal arrangements found previously only in samples from impact craters or the sites of nuclear blasts. And they found similar quartz particles in boundary clays from Denmark, Italy, and Spain. According to Bohor, the quartz grains were lofted high in the atmosphere by the massive impacts and then settled worldwide. "This is direct mineralogical evidence that an impact did occur," he says.

At the same meeting, Jan Smit and Frank Kyte of UCLA reported finding tiny glassy spherules in two iridium-rich boundary sites. The spherules contained the mineral magnetite in a form that is created only when a liquid produced by high-temperature melting crystallizes rapidly. This, the researchers say, is "conclusive evidence that small droplets of very high temperature were involved in deposition of the boundary sediments."

On the basis of this steadily accumulating mountain of evidence, most scientists are now persuaded that some massive extraterrestrial body did smash into Earth 65 million years ago, whether it had anything to do with extinctions or not. Even the normally disputatious Soviets seem convinced. Valentin Ovcharov, writing in *Sputnik* last July, said the evidence suggests "evolution . . . could well be related to cosmic events."

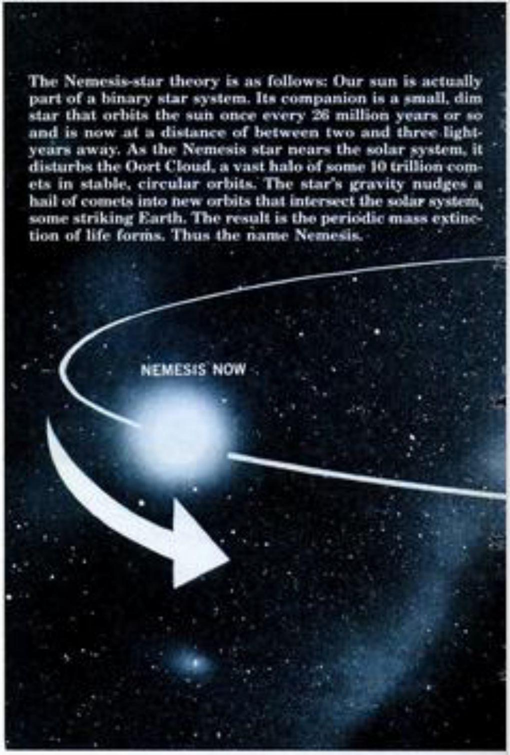
Moreover, evidence is slowly mounting that an even more daring prediction of Luis Alvarez is correct. If a large body struck Earth and caused the C-T extinctions 65 million years ago, he suggested, perhaps the same kind of catastrophe triggered some or all of the other major mass extinctions. Within the last few years, rocks have indeed surrendered signs of the iridium calling card at other mass-extinction boundary layers. Some have been found at the Eocene-Oligocene boundary, 34 to 38 million years ago, accompanied by microtektites—glassy fragments that would have formed in an impact. Last spring a Chinese group reported such a find at the Permian-Triassic boundary, 225 million years old, in Szechuan Province. Also last spring, geologists found one at the end of the Devonian—345 million years ago. And there are (as yet unconfirmed) reports of another Chinese find, in the Yangtse River gorge, at the Precambrian-Cambrian boundary, 570 million years old.

Cyclical destruction

With these finds, proponents of the Alvarez theory believed their case was getting stronger and stronger. Meanwhile, work was progressing that would throw the mass-extinction debate into even greater turmoil, work that culminated in the stunning finding of periodicity in the extinctions.

"In the spring of 1983," David Raup told me recently, "Jack Sepkoski had finished his compendium of temporal ranges of fossil families." This was a massive record of the appearance and disappearance of 3,500 families of marine organisms over a span of 600 million years. "We had it computerized, and he and I were both sort of fiddling around with various kinds of interesting statistical analyses of this marvelous new data set. I was working particularly with questions of whether mass extinctions were biologically selective, so I was making lots of plots and graphs of the entire extinction record . . . . One of the diagrams, which followed a cohort of fossil groups and watched it decay through time, looked like this." Raup showed me a graph in which many wavy, near-parallel lines descended in a series of steps like waterfalls, from left to right. "Where you have steep, almost vertical drops, those are the mass extinctions. And the flat areas show that not much is going on," Raup continued. "And then it just popped out, bang, bang, bang, bang, bang, bang." Raup's finger thumped the diagram at every step. "For this most-recent 250-million-year stretch on the diagram, the extinctions looked regular.

"As I said, it was hard to believe. Jack and I just hung the picture on the wall, and walked around and stood closer and then farther away to see if we were imagining things or not. At one point, while I was attending a conference in Berlin, I pasted diagrams against the window of the Schweitzerhof Hotel—looking east—because I needed a light table."



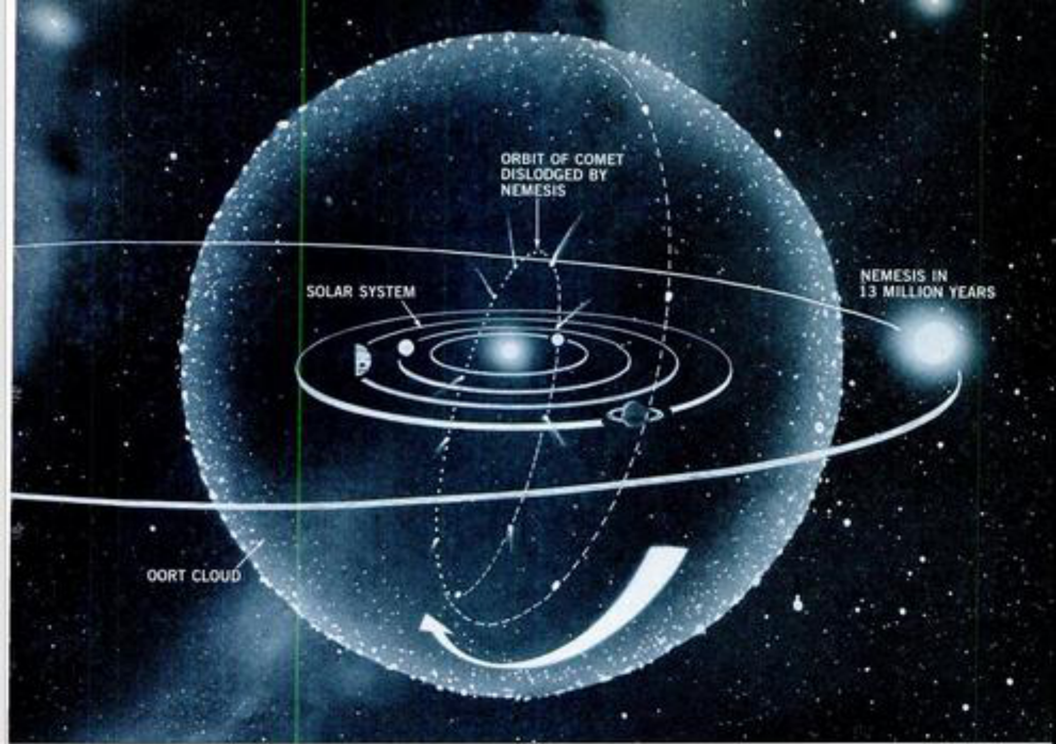
The Nemesis-star theory is as follows: Our sun is actually part of a binary star system. Its companion is a small, dim star that orbits the sun once every 26 million years or so and is now at a distance of between two and three light-years away. As the Nemesis star nears the solar system, it disturbs the Oort Cloud, a vast halo of some 10 trillion comets in stable, circular orbits. The star's gravity nudges a hail of comets into new orbits that intersect the solar system, some striking Earth. The result is the periodic mass extinction of life forms. Thus the name Nemesis.

After months of more-rigorous analysis, using more-sophisticated statistical techniques than those they had used originally, Raup and Sepkoski could plot 10 peaks—mass extinctions—occurring with remarkable regularity, the last one 13 million years ago. The period: 26 million years. "If our statistical work is correct," Raup said, "what we've done is rule out any known hypothesis of random distribution."

But most paleontologists had always believed as an article of faith that the extinctions *were* random. Ironically, an argument in favor of periodicity for mass extinctions had been set out in 1977, in a paper by Alfred Fischer, a respected paleontologist, and his graduate student Michael Arthur, then both of Princeton University. They proposed a period of 32 million years, without nominating any mechanism to account for it.

"Most of us were quite embarrassed by this paper," Raup recalls today, "because obviously it couldn't be right. Periodicity was anathema to us . . . . It's not how geology works . . . . It's like calling on the supernatural. It's anti-everything that Darwin and Lyell taught us . . . ."

Raup and Sepkoski published their findings in the Feb-



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ruary 1984 issue of *Proceedings of the National Academy of Sciences*. The implications, they said, were "broad and fundamental." As an explanation, they wrote: "... we favor extraterrestrial causes for the reason that purely biological or earthbound physical cycles seem incredible...."

Storms of controversy

Long before that paper appeared, however, the news had surged through the scientific community, unleashed by a talk by Sepkoski at an August '83 symposium on extinctions at Flagstaff, Ariz., and by circulating copies of the manuscript. It spawned a fevered excitement of a pitch and scale not often seen in the world of science.

At the center of the maelstrom, along with Raup and Sepkoski, stood Luis Alvarez, whose asteroid-impact theory was intimately concerned. In November 1983, Alvarez received a preprint from Raup. "I didn't believe it when I saw it," Alvarez told me. "I thought their statistical analysis was weak. So I wrote a letter to Dave Raup with my objections. But before I sent it off, I decided to ask Rich Muller, an ex-student of mine, to look it over and play devil's advocate."

Richard Muller is professor of astronomy and physics at the University of California, Berkeley. "Although I was skeptical about Raup's and Sepkoski's findings," he says, "I couldn't agree with all of Luis's arguments against them. I wasn't looking at their analysis... I was looking to see whether their data, in fact, implied periodicity in the extinctions." What could explain it? "I considered a companion star to our sun, one with a period of 26 million years, from the first day."

Muller's concept needed much work, however, to make it plausible. "Over the next two months I worked very hard to come up with the right astronomical model that would fit," he says, "and along the way caught hell from other people." Muller worked on the model at length with Marc Davis, a UC astronomer. The final touches came when Piet Hut, of the Institute for Advanced Study in Princeton, N.J., visited Berkeley a few days before Christmas. As Muller recalls it, "One morning, as Hut, David, and I were discussing everything that had been done until then, Piet suggested a change in one of the models that suddenly made it all work. Over the next week we wrote a paper and sent it off."

Rain of death

In their paper, published in the August 19, 1984, issue of *Nature*, the three astronomers detailed the characteristics of what has been called by many the death star. It is a faint, hitherto-invisible dwarf star, now perhaps 2.4 to three light-years away, with a highly elongated orbit that has a period of 26 million years. In about 13 to 15 million years it will swing near the solar system, passing through the Oort Cloud, named after the Dutch astronomer J. H. Oort of the University of Leiden, who first derived its existence. The Oort Cloud is a reservoir of perhaps 10 trillion comets in stable, circular orbits, forming an insubstantial halo around the outermost reaches of the solar system. When the companion star passes through the cloud, its gravity will kick loose a billion comets and set them streaking inward toward the solar system. Over a period of a million years, a number of comets—perhaps dozens—will inevitably strike Earth, with devastating effect. This is the mechanism that accounts for mass extinctions every 26 million years. (A quite-similar theory was developed

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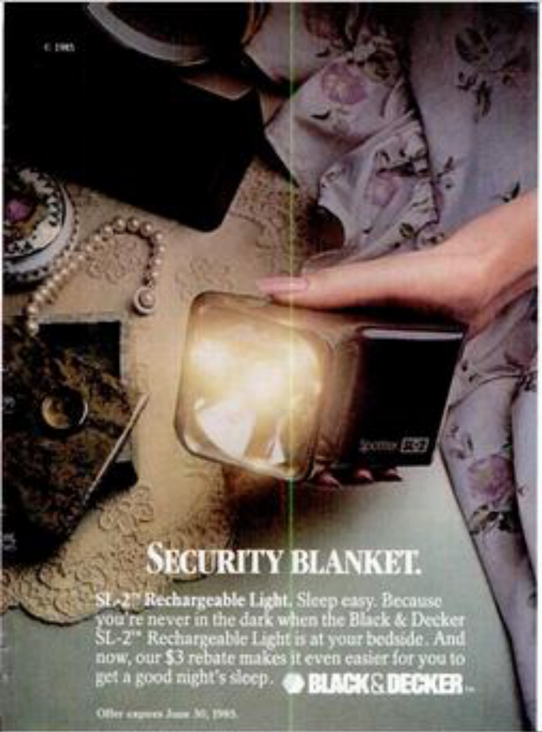

Death star (Continued from page 75)

independently and simultaneously by David P. Whitmire and Albert A. Jackson.)

"If and when the companion is found," Muller, Davis, and Hut wrote, "we suggest it be named Nemesis, after the Greek goddess who relentlessly persecutes the excessively rich, proud, and powerful [a reference to the dinosaurs]. We worry that if the companion is not found, this paper will be *our* nemesis."

The Nemesis notion spurred other conjectures in this heady time. When Richard Muller told Walter Alvarez about the death-star idea, Alvarez suggested that the periodic comet showers stipulated by the theory must have left periodically distributed craters, and that a search of a comprehensive list of craters, compiled by Richard Grieve of Brown University, might reveal something valuable. When the two scientists analyzed 13 craters larger than six miles across, all of which had been accurately dated between five and 250 million years ago, they found a period of 28.4 million years, close to that found by Raup and Sepkoski—and in phase with the extinction record.

A jubilant trio—the Alvarezes, father and son, and Richard Muller—placed a conference call to Raup and Sepkoski to tell them the good news. "All of a sudden they were believers," said Raup. "They could now really accept the periodic-extinction idea because they could corroborate it with their own analyses of cratering.

"Jack and I were still skeptical about the craters, however. The next day we tried our own selection of craters with the statistical techniques we'd used for the extinctions—and lo and behold the results matched Walter's perfectly."

The fireworks are not over. Since last spring, astronomers at UC's Leuschner Observatory have been using an automated 30-inch telescope hooked to a computer to examine 3,000 red-dwarf stars that are assumed to be candidates for Nemesis. Muller explains: "The right star will appear to move back and forth in front of the background stars ... with a motion that is greater than that seen for any other star." If nothing is found, the search will be extended to more-southern skies this spring.

Alternative theories

And Nemesis is not the only recent theory propounded to explain periodic mass extinctions. One holds that comet showers are triggered about every 30 million years when the solar system passes through the galactic plane, encountering vast clouds of material. Another suggests that the long-hypothesized (and long-sought) Planet X, orbiting the sun between the outermost planets and the Oort Cloud, might be the trigger. It is safe to predict that more theories will be forthcoming.

Meanwhile there are groups that challenge virtually every conjecture cited above. For example, the alleged periodicity both of mass extinctions and of impact craters is under heavy attack from several quarters, either on the grounds that the statistical analyses are flawed or that the evidence is insufficient. Others believe Nemesis could not have remained in a stable orbit for 250 million years. The arguments are bound to continue for a long time.

After all, science is a serious game of thrust and parry, theory and counter-theory, evidence marshalled and evidence disputed. The arguments explored here, some as gnarled as the tree of life itself, will go on for a long time, propelled by humanity's conflicting ideas about its nature and by its unquenchable desire to understand its home and its history.