together to produce the effect. One of them binds antigen and the other recognizes self, although in this case the restriction is linked to immunoglobulin genes. According to Gershon, these results must be explained in terms of dual recognition if the two molecules act on the same cell. They cannot be interpreted in terms of altered-self theories because the self-recognizing molecule will not work by itself.

Gershon sums up the current status of T cell receptor theories in the following words. "People came to Rüdesheim with certain commitments to possible theories. Extremely interesting data were presented by each to establish his view. As clever as the experiments were, people with the opposite view could think of more clever explanations for them. The tie breaker has not yet appeared in this particular match."

The ultimate tie breaker will be the isolation of the receptor molecules themselves and the identification of the genes coding for them. Because of the evidence that heavy chain variable genes code for a portion of the receptor, researchers are looking for gene rearrangements during the development of T cells analogous to those known to occur during the differentiation of B cells. The rearrangements might serve as a guide to the receptor genes. So far, as reported by Susumu Tonegawa, who recently moved from the Basel Institute of Immunology to MIT. "We don't know anything about the structure of the genes coding for the T cell receptor." His laboratory and others have shown that J_H gene segments, which code for the region that connects the variable and D regions with the constant region of the heavy chain, are not used to code for the receptor. That does not rule out participation of the V region, however, and Tonegawa is still looking for a rearrangement involving this gene segment.

Although there may still be uncertainties about the role of the thymus and certainly about the nature of the T cell receptor, researchers have come a long way in the past decade toward understanding the working of histocompatibility antigens. Katz says, "We have learned three things indisputably. Cells are restricted to recognizing self; that self-recognition is a crucial aspect of their function; and they have sufficient plasticity to adapt to the environment where they differentiate." One day there may even be agreement about the T cell receptor.—JEAN L. MARX

Additional Reading

1. Overview of the major histocompatibility complex: B. Benacerraf, *Science* **212**, 1229 (1981).
2. Experiments with chimeras: D. L. Longo, L. A. Matis, R. H. Schwartz, *Crit. Rev. Immunol.* **2**, 83 (1981).
3. One-receptor view of T cell behavior: P. Matzinger, *Nature (London)* **292**, 497 (1981).
4. Two-receptor view: D. H. Katz, *Adv. Immunol.* **29**, 137 (1980).
5. Short review on "Thymic education": M. J. Bevan, *Immunol. Today*, in press.

Impact Looks Real, the Catastrophe Smaller

Diverse specialists now agree that the evidence for a huge asteroid (or comet) impact is impressive, but they have scaled down its effects

The notion may have seemed fanciful at first, the idea that an asteroid the size of Manhattan might have rammed into Earth, darkened the skies for 3 years with the dust it kicked up, and killed off all manner of plants and animals including the dinosaurs. But the kernel of evidence that in early 1980 inspired this particular version of mass extinction received early support from some scientists (*Science*, 31 October 1980, p. 514). At a meeting* last month called to take a serious look at the proposal, geochemists, as well as paleontologists, geologists, and physicists, agreed that there really do seem to be chemical traces of an impact 65 million years ago.

The theory also received a boost at the meeting when experts resolved several problems concerning its physical plausibility. The most pivotal change was forced when, late on the first morning of the meeting, Brian Toon of the National Aeronautics and Space Administration's Ames Research Center at Mountain View, California, shrank the ominous 3-year period of darkness down to a more comfortable 3 months or so. That pleased the terrestrial paleontologists, who had been insisting all along that the proposed catastrophe was much too severe. Such a scenario simply did not jibe with their fossil record of limited, though extensive, extinctions at the boundary between the Cretaceous and Tertiary periods 65 million years ago.

The problem has been with the dust. The originators of this particular impact scenario,† Luis Alvarez, Frank Asaro, and Helen Michel of the University of California's Lawrence Berkeley Laboratory and Walter Alvarez at the University of California at Berkeley, modeled their "great darkness" on the atmospheric effects of the eruption of Krakatau, as reported in an 1888 publication. Toon pointed out that the Alvarez group had incorrectly assumed that the dust stayed up for the full 3 years that dramatic sunsets had been seen around the world. Rather, the dust probably fell out in about 3 months, Toon said, leaving the volcano's sulfurous gases to form a persistent haze in the stratosphere.

Even if the amount of dust were to be increased a thousandfold or more, it would not help, Toon noted. Particles as small as 0.5 micrometer could last 1 to 2 years if not for their inevitable tendency to stick to one another, form larger particles, and fall out at the faster rates typical of larger particles. According to calculations by Toon and James Pollack of Ames, the longest that the "darkness at noon" could have lasted was 4 to 6 months.

After the drastic downward revision of the duration of the darkness, paleontologists could finally make some sense of the impact hypothesis. The Alvarez group had postulated 3 years of darkness, cessation of photosynthesis, and the complete collapse of food chains on land and in the sea from the bottom up. Survivors would have included plants regenerated from long-lived seeds, spores, and root systems, and the small animals that could have eaten insects and decaying vegetation.

*Conference on Large Body Impacts and Terrestrial Evolution: Geological, Climatological, and Biological Implications, 19 to 22 October 1981 at Snowbird, Utah; sponsored by the Lunar and Planetary Institute and the National Academy of Sciences. Meeting abstracts may be obtained from Library/Information Center, LPI, 3303 NASA Road 1, Houston, Texas 77058. Enclose a check for $3 (U.S. domestic and foreign surface mail) or $5 (foreign airmail).

†W. M. Napier and S. V. M. Clube of the Royal Observatory, Edinburgh, have also suggested that the blockage of sunlight by the dust from a large impact could produce mass extinctions [*Nature (London)* **282**, 456 (1979)].

Looking at the terrestrial fossil record, paleontologists see nothing like the effects of a 3-year darkness. Tropical plants, the ones least equipped to resist prolonged darkness and the resulting cold, came through in the best shape. Animal species seem to have perished or persisted without regard to body size or eating habits. Expert after expert took the podium to make the same point—on land, the pattern of extinction and survival does not fit that expected of years of darkness. They also stood firm on another favorite point. The Cretaceous-Tertiary mass extinctions did not *all* occur suddenly or simultaneously, they said, as a global catastrophe would demand. Although the rate of extinction was unusually high at about that time, some species had disappeared millions of years before and others lingered long after.

If the paleontologists would not allow major catastrophic extinctions on land, they were happy to have them among certain groups of organisms in the ocean. Hans Thierstein of the Scripps Institution of Oceanography told of his efforts to see exactly how accurate a record the cores of the Deep Sea Drilling Project are. He corrected the microfossil record of extinctions for the blurring caused by the stirring of the sediment by burrowing animals. He also checked for any missing parts of the sedimentary record due to erosion or a lack of deposition. Thierstein concluded that the Cretaceous-Tertiary extinctions of open-ocean, floating species represented "a major environmental event. It is unique in its suddenness," he said. "There's nothing comparable that we know of in the Phanerozoic [the past 500 million years]."

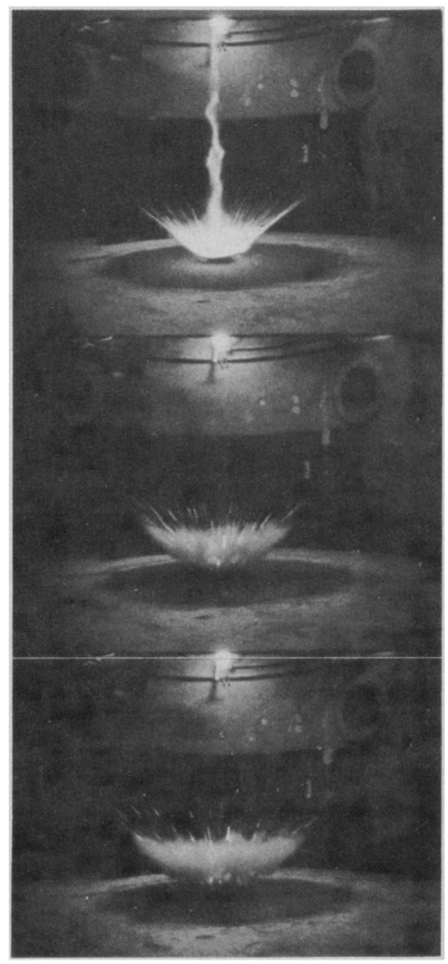
The marine extinctions were not only sudden but also extensive—49 percent of all genera of floating marine organisms disappeared, according to Thierstein's count. Dale Russell of the National Museum of Natural Science in Ottawa had estimated 44 percent for the same group, 48 percent for swimming marine organisms, and 47 percent for bottom-living organisms. But only 14 percent of freshwater genera and 20 percent of terrestrial genera became extinct at that time. "We have to take these patterns into account," Thierstein said. "Darkness is a very good mechanism that could account for the pattern that we have."

David Milne of Evergreen State College had already set the stage for Thierstein when he argued in an earlier talk that darkness, if it were brief, could have inflicted grievous damage on marine ecosystems while only lightly stressing continental plants and animals, as seems to have been the case. Milne and Christopher McKay of the University of Colorado found that the microfauna of modern seas would consume their food reserves within 10 to 100 days of the beginning of a blackout, precipitating the collapse of the food chain. Terrestrial ecosystems would still have to contend with subfreezing temperatures for perhaps twice the duration of the darkness, according to Toon and Pollack's calculations. Nonetheless, a brief darkness appealed to paleontologists because it offered a means of decoupling the marine and terrestrial extinctions. With such a short-term darkness, the geochemists and planetary scientists could have their impact and paleontologists could have their gradual extinctions on land brought about by changing environmental conditions.

Another group at the Snowbird meeting, the physicists specializing in the mechanics of impact cratering, also found that they no longer have fundamental objections to the impact hypothesis of extinctions. Their major problem had been the apparent high proportion of meteoritic material, up to 10 percent, in the thin clay layers at the Cretaceous-Tertiary boundary. Large meteorites had been thought to mix with a mass of crustal rock many times their own size, thus swamping their exotic chemical composition with ordinary terrestrial rock. There should have been little of the asteroid left in any one place for the geochemists to recognize, according to this thinking.

Researchers found a number of possible ways around the dilution problem. Jay Melosh of the State University of New York at Stony Brook reported on his "crude piecing together of physical principles," intended to determine what happens when an asteroid hits a 5-kilometer-deep ocean at 72,000 kilometers per hour. Within half a second of contact, the seawater trapped beneath the asteroid would be pressurized to more than 4 million atmospheres, according to Melosh's calculations. Once this compressed water begins to expand as superheated steam, the asteroid, now quite thoroughly pulverized, would be sprung back toward the upper atmosphere at 10,000 to 20,000 kilometers per hour. Melosh found that a supersonic plume, much like the jet from a rocket nozzle, could carry the meteoritic material plus hundreds of cubic kilometers of seawater in the form of ice crystals higher than 100 kilometers. Unlike an impact on land, Melosh noted, such an impact in the ocean would create little dust from Earth's crust, leaving the clouds of ice crystals as a major modifier of climate and a possible agent of extinction.

On land, a large impact would be dustier, but it could produce a darkening and the observed chemical traces of an asteroid, according to a computer model developed by John D. O'Keefe and Thomas Ahrens of the California Institute of Technology. They found that ejecta thrown upward during the early stages of an impact need not plow through the atmosphere but are actually carried upward with the air that is rushing away from the impact. This early ejecta also contains the highest proportion of meteoritic material. Thus, enough dust rich in meteoritic material could reach high altitudes and eventually spread around the globe. The spreading of the initial dust cloud remains a poorly understood but crucial step. No one can show at the



Peter Schultz and Donald Gault

A laboratory "asteroid" impact

In this series of photographs, taken 1/400th of a second apart, the NASA-Ames Vertical Gun has shot a 0.25-inch aluminum projectile into a layer of pumice dust at a velocity of 21,600 kilometers per hour. There is an argon atmosphere with a pressure of 720 millimeters. The final crater was about 15 centimeters in diameter. Similar experiments simulating impacts in the ocean are also being conducted.

moment exactly how it would spread fast enough to avoid rapid agglomeration and fallout.

A bit surprisingly perhaps, the geochemical evidence of an impact, which first prompted all the speculation about extinctions, generated the least discussion at the meeting. A year ago, scientists in a variety of fields cast a suspicious eye on the interpretation of thin sedimentary layers rich in iridium, osmium, palladium, nickel, and gold as layers of dust from an asteroid impact. They offered various alternative explanations, usually involving concentration through natural processes of the meteoritic dust that slowly but steadily settles onto Earth. But there seemed to be general agreement at Snowbird that the alternative explanations proposed to date have serious if not fatal problems.

For one thing, the iridium anomaly at the Cretaceous-Tertiary boundary has now been reported in marine sediments at 15 sites in Italy, Denmark, Spain, the South Atlantic, the North Pacific, Texas, and New Zealand. In addition, a group headed by Charles Orth of Los Alamos National Laboratory reported that they had confirmed their discovery of a nonmarine Cretaceous-Tertiary anomaly in northern New Mexico (*Science*, 19 June, p. 1376). They found the iridium anomaly in the same sediment layer in which they found their first anomaly, but 50 kilometers away. Both are at the base of a coal layer formed in a swamp. The New Mexico anomaly has presented an impassable obstacle so far to those looking for more mundane explanations of iridium anomalies. Natural processes that could possibly have concentrated iridium on the sea floor do not seem to work in swamps.

Not only are geochemists finding iridium anomalies at the Cretaceous-Tertiary boundary almost everywhere they look, but they are also failing to find them in preliminary studies of other parts of the sedimentary record. Frank Kyte and John Wasson of the University of California at Los Angeles (UCLA) reported that an ongoing systematic search for iridium in a piston core of North Pacific red clay has proved fruitless, except for the finding of the Cretaceous-Tertiary anomaly. So far, they have covered 14 million of the core's 70 million years of sedimentation and have found nothing else resembling the Cretaceous-Tertiary anomaly. The failure to date to find numerous anomalies of different ages suggests that they are no ordinary phenomenon, as researchers had feared they might be.

Kyte, Wasson, and Zhiming Zhou, also at UCLA, did find a distinct iridium anomaly in 2.3-million-year-old sediment from the Antarctic Ocean. Led to the iridium layer by unusually high concentrations found by others in a section of core during a broad survey, they found that much of the iridium of at least one sample resided in a couple of millimeter-size particles. They bear a strong resemblance, the UCLA group noted, to the kind of material that would be ablated from a meteor as it passed through the atmosphere. No global extinctions are associated with the age of this anomaly. Whether it is a local, regional, or global anomaly remains to be seen.

Alternative explanations proposed to date have serious if not fatal problems.

The only other iridium anomaly outside of the Cretaceous-Tertiary boundary may also be associated with a large impact. R. Ganapathy of the J. T. Baker Chemical Company in Phillipsburg, New Jersey, squeezed in a quick unscheduled talk to announce the discovery of an iridium anomaly in a Caribbean sediment core 30 centimeters from a layer of microtektites. These submillimeter globules of glass, which are thought to be thrown out from large meteorite impacts, are part of the 13 billion tons of microtektites strewn from Georgia to the Indian Ocean 34.4 million years ago by an as yet unidentified impact.

The temptation was great to associate the iridium with this impact and perhaps with the major extinctions at the boundary between the Eocene and Oligocene epochs (37.5 million years ago), but gaps in space and time make the situation a bit too muddled for that. The boundary date could change with the application of more reliable dating techniques, or the iridium may be associated with a second kind of microtektite found at the iridium peak by Billy Glass of the University of Delaware. Meeting participants regarded the whole matter as intriguing, but a bit odd. Neither Ganapathy's anomaly nor the UCLA group's 2.3-million-year-old anomaly seemed to detract from support for the significance of the Cretaceous-Tertiary anomaly.

Excitement was running high by midmeeting when Michael Rampino of the Goddard Institute for Space Studies in New York attempted to raise serious questions about the interpretation of the iridium anomaly as the trace of an impact. Rampino drew together a number of known processes that might concentrate in a single layer the iridium that drifts to the surface from space. After his talk, every questioner who took the floor rose to the defense of the Cretaceous-Tertiary anomaly. How could any of these processes form an anomaly at the base of a coal bed? None of them could, Rampino conceded. The maximum time allowed for the formation of the anomalous layer at some sites was some tens of thousands of years, another questioner noted. How long would these processes require? About 1 million years was the answer. A third noted that a combination of earthly processes that produced the same proportions of exotic elements as found in meteorites was difficult to accept. Only later did anyone publicly defend Rampino's effort. Karl Turekian of Yale University, a prominent geochemist, cautioned during the meeting's closing discussion that, despite all the positive evidence, "iridium is a part of our Earth and we don't understand everything that can concentrate iridium. There's a danger that we'll accept this prematurely."

Even if an impact 65 million years ago cannot yet be taken as absolute fact, meeting participants certainly accepted it as a strong working hypothesis. Some of the more conservative observers would like to see additional cases of anomalies at the Cretaceous-Tertiary boundary in nonmarine sediments, and broader, more thorough searches of the sedimentary record away from the boundary. An unequivocal association of an anomaly with tektites would not hurt either. On the biological side, researchers are anxious to know how individual species and whole ecosystems would respond to the stresses of an impact—not only darkness, but also heat, cold, nitrogen oxides, acid, and a host of other impact-related agents now being discussed as possible causes of extinctions.

To the paleontologists and geologists, the most exciting prospect may not be the explanation of some mass extinctions. Rather, it is the possibility of telling geologic time with unprecedented precision. They have been able to say with great precision what the order of events was at any one site. The difficulty has been telling the order of events at widely separated locations, especially when one event was in the ocean and another on land. If a great impact did deposit an identifiable layer over the globe in a single geologic instant, it would be the ultimate time marker.

—RICHARD A. KERR