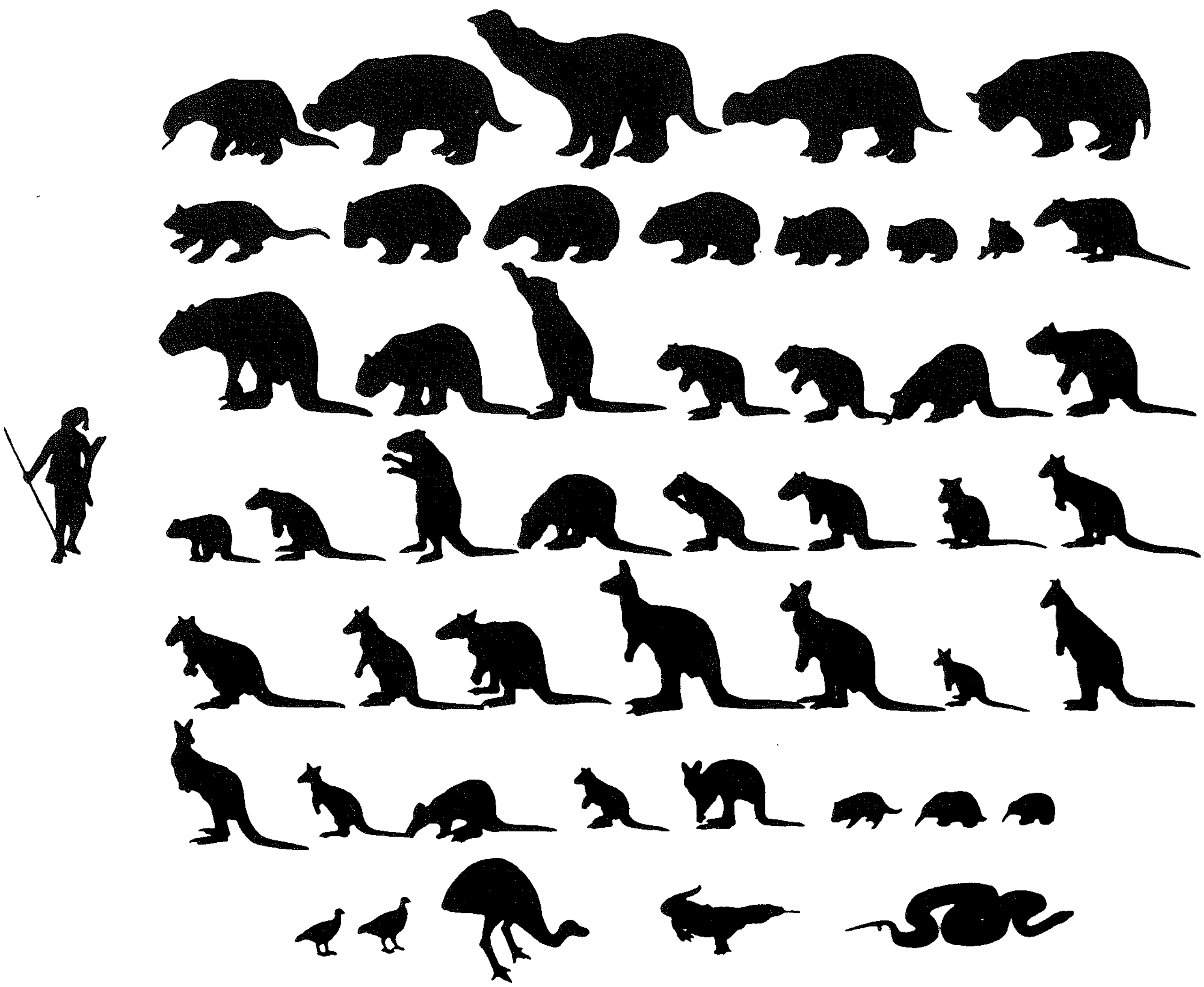
ANTHROQUEST

news of human origins, behavior and survival

Number 37 L.S.B. Leakey Foundation News Spring 1987

EXTINCTIONS

Abstracts of Lectures Given at the October Symposium Co-sponsored by the Associates of the Leakey Foundation and the Los Angeles County Museum of Natural History



Profiles of extinct large Australian marsupials.

Please turn to page 10.

PRESIDENT'S MESSAGE

Dear Fellows and Members of the Leakey Foundation:

"Recent rapid evolution of human intelligence is not only the cause of, but also the only conceivable solution to, the very serious problems that beset us. A better understanding of the nature and evolution of human intelligence just might help us to deal intelligently with our unknown and perilous future." – Carl Sagan, *Dragons of Eden*, 1978.

Last fall, the Leakey Foundation held a symposium jointly with the Los Angeles County Museum of Natural History entitled, "Extinctions! Who's Next?" It is evident that extinctions have been a part of the billion or more years of the history of life on earth, with a massive species extinction possibly every 26 million years. David Western's research has shown that African elephants have, by foraging the dense tropical forests, cleared small areas for species diversification. So have massive extinctions in the remote past provided opportunity and environmental slots for many new species – plants and creatures of all kinds.

Last year was the Year of the Comet and I have yet to talk to someone who had a clear and exciting view of the famous Halley's Comet that we had heard so much about from our parents and grandparents. However, reading *Comet* by Carl Sagan and Ann Druyan was for me the excitement I missed in not seeing the comet in the sky. The appearance of comets has indeed brought drama and rich speculation to those who have witnessed them throughout the ages.

There is evidence that meteors, asteroids and probably comets from our own galaxy and certainly from our solar system brought about many of the extinctions in prehistoric times, possibly with 26 million year periodicity. A most interesting article on this subject appeared in the *National Geographic* in September, 1986. Geologist-astronomers Eugene and Carolyn Shoemaker, as a part of their much wider research, are on the watch for collision courses with the earth of such dangerous massive bodies from space. As pointed out by Dr. Shoemaker, the hazard to humankind is remote. Further, it is possible to devise a spacecraft equipped with a propulsion system "to nudge the object into a non-threatening orbit."

There is no evidence that I know of that extinctions on earth from causes located in outermost space have ever occurred, and they are not a likely hazard in spite of the fascinating probability of advanced intelligence in some other of a million or more solar systems.

Within the space of our earth's atmosphere, there is disturbing news of a hole in the ozone layer in the upper atmosphere, and also an increasing greenhouse effect in the lower atmosphere which will be very difficult to arrest or reverse. There seem to be major problems developing from widespread use of pesticides and agricultural chemicals. We will be hearing and reading more and more about these problems in the coming months and years. Though extremely stressed, it would seem that our species should be able to adjust and survive environmental changes due to these problems, as we survived the ice ages. However, many other species of fauna and flora will become extinct, accelerating species extinctions caused this time possibly by our use of fluorocarbons in damaging the ozone layer and certainly by our use of hydrocarbons and agricultural chemicals.

When I travel to Southeast Asia and Australia, as I have often done in the last few years, I find real concern, not because of atomic energy as such, but for the divisive stress and the threat of warfare in the northern

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THE L.S.B. LEAKEY FOUNDATION

The L.S.B. Leakey Foundation was established in 1968 by a group of eminent scientists and informed lay people who recognized a critical need to strengthen financial support for new multi-disciplined research into human origins, our evolving nature and environmental future. It was named in honor of the man who had become known as "the Darwin of pre-history," Dr. Louis S.B. Leakey.

The Foundation sponsors:

International research programs related to the biological and cultural development of humankind.

Long-term primate research projects which may help us to understand how we evolved as a species.

The training and education of students in these fields.

Conferences, publications of scientific papers, and educational programs designed to disseminate knowledge relevant to our changing view of humanity's place in nature.

The L.S.B. Leakey Foundation is a public foundation. All contributions are tax-deductible as provided by law.

THE L.S.B. LEAKEY FOUNDATION NEWS

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Production Editor, Jan Slater

AnthroQuest is published by the Foundation as a service to its members. Single copy price, $1. L.S.B. Leakey Foundation, Foundation Center 1-7, Pasadena, CA 91125.

Telephone (818) 449-0507

SYMPATRIC GORILLAS AND CHIMPANZEES IN GABON

Caroline Tutin and Michel Fernandez
Centre International de Recherches Médicales de Franceville, Gabon
and the Psychology Department, University of Stirling, Scotland

Studying the behavior and ecology of sympatric gorillas and chimpanzees provides a unique opportunity to examine the similar and different ways in which these two species of great ape, our closest living relatives, have adapted to the same environmental conditions. Information on how gorillas and chimpanzees exploit the food resources available, their ranging behavior, their interactions with the sympatric fauna and especially with each other, and details of their social organizations and social relationships may help to define some of the possible social, behavioral and ecological strategies that were available to our human ancestors. Much is known about the natural lives of chimpanzees, thanks to the long term studies in Tanzania by Jane Goodall and the Japanese team led by Drs. Itani and Nishida. Similarly, thanks to the research of George Schaller and the late Dian Fossey and her colleagues, the ecology and behavior of the mountain gorillas of the Virungas is very well documented. In contrast, there is very little information available about the ecology and behavior of either western lowland gorillas or chimpanzees in tropical rainforests of west-central Africa, where the two species co-exist.

Studies in the late 1960s and early '70s of unhabituated western lowland gorillas in Equatorial Guinea, by Sabater Pi and Jones, and in Cameroun, by Julie Calvert, found that the basic social structure of western lowland gorillas is the same as that of mountain gorillas: a cohesive, stable group led by a single fully adult male (the silverback) with several adult females and their offspring. The groups of western lowland gorillas tend to be smaller in size (medium: five individuals) and less variable in number (range two to 12) than those of mountain gorillas in the Virungas (medium: six, range two to 21). A more striking difference between mountain and western lowland gorillas was in their diets, as the latter consume a variety of succulent fruit in addition to foliage while mountain gorillas are almost exclusively folivorous. The amount and variety of fruit consumed by western lowland gorillas appear to be very variable but few quantitative data are available. This dietary difference between mountain and western lowland gorillas and the variation between different populations of western lowland gorillas are certainly related to the availability of succulent fruit in different habitats: extremely rare in the montane habitat of the Virungas, more common in lowland secondary forest with a history of human disturbance, and most common in primary tropical rainforest. The quantity of fruit available to and eaten by gorillas has not only nutritional implications (fruit is superior to foliage in terms of energy per unit weight) but also introduces seasonality and distribution as important variables in food availability.

Caroline Tutin.

The social structure of chimpanzees differs from that of gorillas. Chimpanzee communities range in size from 30 to 100 individuals including many adult males with as many, or more, adult females and their offspring. The members of a community rarely assemble all together but spend their time alone, or in sub-groups of variable size and composition which may change membership frequently during a single day. Chimpanzees are primarily frugivorous and the availability of ripe fruit is one factor determining the size and stability of sub-groups. Chimpanzees occurred sympatrically with the gorillas studied by Sabater Pi and Jones and by Calvert, but in both cases sites in secondary forest and/or abandoned plantations were selected for their studies of gorilla feeding. Western lowland gorillas are known to occur at higher population densities in areas of secondary forest where light-loving herbaceous plants grow in great abundance. It is, however, important to note that these same plants do occur at low density in primary forest where they colonize in light gaps created by natural tree-fall. Chimpanzees tend to avoid areas of secondary forest and occur at higher densities in primary forest. This led to a belief that western lowland gorillas occurred only, or largely, in areas of secondary growth and were thus rarely found in exactly the same forests as chimpanzees.

Michel Fernandez and I conducted a nationwide census of chimpanzee and western lowland gorilla populations in Gabon from 1980 to '83 and found that the two species were truly sympatric throughout the majority of forested areas in the country. After the completion of the census, which was financed by the Gabonese Centre International de Recherches Médicales de Franceville (CIRMF), we were able to establish a field station for long term behavioral and ecological studies of sympatric gorillas and chimpanzees. The construction of the station was again funded by CIRMF and we received generous help from the Leakey Foundation which, in 1984, awarded me the first Great Ape Fellowship. We chose the forests of the Lopé Reserve in central Gabon as our

Gorilla.

study site for two reasons: First, the Lopé was the only large area (5,000 square kilometers) in Gabon to benefit from legal protection from all hunting; and second, preliminary surveys had shown that both gorillas and chimpanzees occurred at similar population densities and utilized the same areas of forest.

Our first aim at the Lopé is to habituate the gorillas and chimpanzees to the presence of observers, an essential prerequisite to collecting quantitative data on their ecology and behavior. Habituation involves overcoming the initial reaction of fear of humans and advancing to the point where the observer is accepted as a neutral part of the environment. This is achieved by repeated exposure to peaceful humans which, over time, convinces the apes that it is easier to accept the presence of these strangers than to continually disrupt their normal activities by running away. However, fear of the unknown is adaptive and habituation can only be advanced if the apes can initially observe humans from a distance that they consider as safe. Unfortunately, these conditions are very difficult to fulfill in the tropical forest of the Lopé as visibility at ground level is so limited. We try to overcome this problem by following the example of Dian Fossey by making specific non-threatening sounds when close to, or approaching, the gorillas or chimpanzees. Advance auditory warning of our presence does reduce the number of times that we frighten apes by a sudden, unexpected appearance but visual input does appear to be very important to successful habituation and progress has been slow.

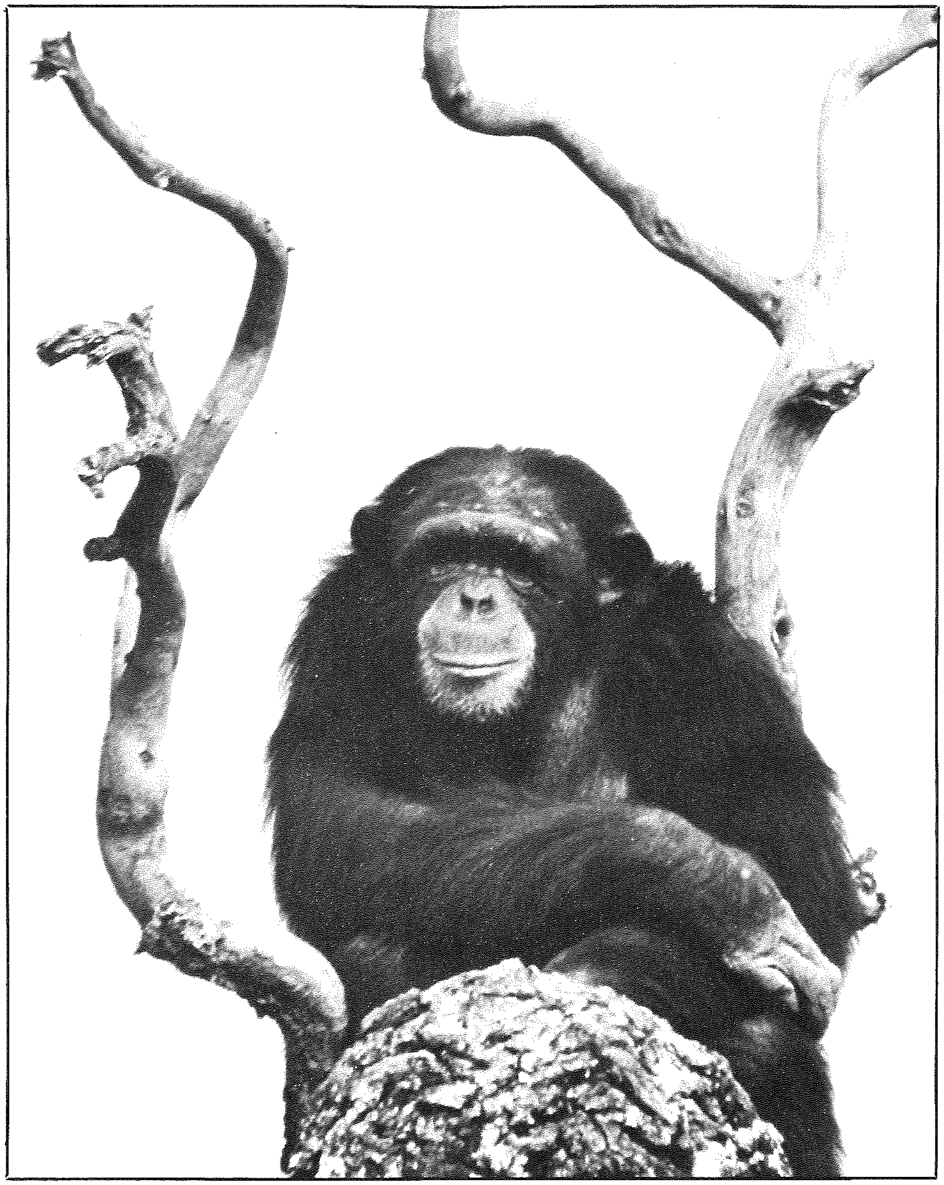
Of interest are differences in responses to our presence shown by the two species. If we are spotted by adult female or immature gorillas, their reaction is very often pure curiosity with no detectable fear. But if the group silverback, on detecting our presence, reacts with fear or alarm, then all members of his group will follow his lead and flee from us. Chimpanzees rarely vocalize upon discovering human observers and often leave the area without communicating their fear to other chimpanzees, who might remain unaware of our presence. The exception to this is that mothers will always collect their infants and wait for juveniles (their presumed offspring) before leaving. What is striking is that 1) young gorillas take their cues from the behavior of the silverback, whereas young chimpanzees look to their mothers if in doubt as to how to react to an unfamiliar situation; and 2) adult male chimpanzees will often flee discreetly from a perceived danger without warning other members of the group.

Field procedure at this stage in our research involves going into the forest daily and searching for the gorillas and chimpanzees. This means examining any feeding remains, feces, nests or other indications of where the apes have been and using these indirect indices of their activities to track them until approach is possible. Vocalizations can be very useful in localizing the apes but while we frequently hear chimpanzee pant hoots, which carry over long distances, it is less common to hear gorillas calling as most of their vocalizations are quiet, serving to communicate within the close-knit social group. While we are searching, we collect whatever data we can on the foods eaten by the two species. These data are still preliminary and largely qualitative but indicate that lowland gorillas at Lopé are probably the most frugivorous of any population yet studied and that there is a substantial overlap in the foods eaten by the gorillas and the chimpanzees.

Most of our information on the species of fruit eaten by the apes of the Lopé comes from identification of the particulate remains in feces. During 34 months (January 1984 – October 1986) we have sieved 1,634 gorilla and 549 chimpanzee fecal samples. Remains of at least one species of fruit were found in 97 percent of gorilla and in all of the chimpanzee samples. At least 78 different species of fruit are eaten (species of the same genus sometimes have seeds that are indistinguishable). Of these, 63 are eaten by gorillas and 68 by chimpanzees and 45 species constitute important foods for both species of ape. The majority of fruit eaten by both species (79 percent for gorillas, 83 percent for chimpanzees) is succulent; the flesh is consumed and the seed usually swallowed to pass intact through the digestive system. Sixty five percent of the species of fruit eaten by gorillas and 71 percent of those eaten by chimpanzees are produced by trees 15 to 35m in height. Gorillas of all age-sex classes have been observed to climb regularly to obtain fruit (as well as young leaves, bark and flowers) and while adult gorillas in general, and silverback males in particular, climb and move through trees more slowly and cautiously than chimpanzees, they have been observed feeding at heights of up to 30 meters.

While gorillas at the Lopé eat large quantities and a considerable variety of fruit, they are by no means totally frugivorous. Almost all gorilla feces contained remains of non-woody fiber and fragments of green leaves but these could almost never be identified taxonomically. We have observed, or found clear trail evidence of, gorillas feeding on 43 different non-fruit foods: mainly leaves, stem pith and bark, and the flowers of one tree species. Gorillas and chimpanzees at the Lopé regularly consume weaver ants (*Oecophylla sp.*) and some other species of insects. Mammalian remains have never been found in gorilla feces and have been recorded in only 0.7 percent of chimpanzee samples.

So, gorillas and chimpanzees at the Lopé eat many of the same foods and it seems likely that the percentage overlap in diet will increase as our study continues. Gorillas eat more foliage than chimpanzees especially at times when fruit is scarce. The large qualitative overlap in diet between the two species suggests that some kind of competition over access to food resources is likely to occur. It is possible that such competition is not intense most of the time but it might become so when food is relatively scarce. Already, we have noted variation in the availability of ripe, succulent fruit over the annual cycle and between successive years. In addition to studying the apes, we monitor plant phenology, noting the presence of flowers and fruit and recording leaf production for 60 species of food plants. These data, combined with details of the ranging patterns, feeding behavior and interactions between gorillas and chimpanzees, should allow us to assess and understand the nature of any competition existing between the two species.



Chimpanzee.

During the past three years there have been 19 occasions when observers have had clear evidence of chimpanzees and gorillas being in the same area of forest. On eight of these occasions, observers were close to and watching groups of gorillas which made no discernable response to chimpanzee vocalizations from distances of 100 to 500m. On five further occasions, vocalizations from both chimpanzees and gorillas were heard in the same area with distances between the two species estimated at 50 to 300m. In all of these cases, calls of the two species were interspersed and dominated by pant hoots from the chimpanzees and chest beats from the gorillas, suggesting that they were responding to each other's calls, as no obvious "third party" was involved, and only once were alarm vocalizations (threat barks from gorillas) included. Four of these vocal exchanges were heard during the day and the fifth occurred in the middle of the night when both species were presumably in their nests.

The remaining six cases were known to have been close range encounters and, almost certainly, all included visual contact between the gorillas and chimpanzees. Twice chimpanzees were observed while gorilla groups were being followed. In the first case, a solitary adult male chimpanzee passed within 25m of feeding gorillas with no discernable response to them but he fled silently on seeing the observer. In the second case, an adult female chimpanzee and an infant of approximately two years of age were feeding in a tree when a gorilla group passed below. They continued to feed, apparently ignoring the gorillas, but on detecting the observers, they climbed slowly to the ground and moved off in the opposite direction, passing within 20m of several gorillas with no audible interaction. On three occasions a young chimpanzee (twice a juvenile and once an infant) was known to have approached gorilla groups and to have been closer to the gorillas than to their mothers. In all cases the chimpanzee fled on detecting the observer but these incidents suggest that young chimpanzees are sometimes attracted to gorilla groups and it is possible that youngsters of the two species play together. The final interaction was aggressive and occurred close to a large fruiting tree. The encounter was not directly observed although we were only 50m away, but from the vocalizations, sounds of movement and subsequent examination of the site, general events can be reconstructed. A group of gorillas and several sub-groups of chimpanzees had been in the same area for almost three hours but never closer than several hundred meters. The gorillas had fed extensively in a large tree bearing much ripe fruit and were still close to this tree (probably resting on the ground below) when a smallish subgroup of chimpanzees arrived in the immediate vicinity. The silverback gorilla charged through the vegetation giving threat barks; the chimpanzees gave alarm calls and after 10 minutes moved rapidly away from the gorillas.

From these preliminary data it seems that close encounters between gorillas and chimpanzees are rare events and vary in context from aggressive through passive avoidance to affiliative. It seems that polyspecific associations, so commonly formed by different species of arboreal monkeys at the Lopé, do not occur between the two species of ape. More data and especially observation of habituated groups of gorillas and chimpanzees are needed before we can describe the full range and true frequency of their interactions.

Research on the gorillas and chimpanzees of the Lopé is in its infancy and many more years are required to gain a full understanding not only of the way in which these two similar species coexist but also of the adaptive significance of their different forms of social organization. Of particular interest will be the similar or different ways that the two species cope with periods of low food availability, as periods of hardship were probably decisive during human evolution. Evidence from field studies suggests that chimpanzees might be the best model for speculation about the ecology and behavior of human ancestors: The ecological adaptability of chimpanzees is demonstrated by the wide range of habitats in which they occur; and their behavioral adaptability is reflected by cultural differences between populations and their skill as tool users. It seems clear that the flexible social structure of chimpanzees is the secret of their ecological adaptability: They can form large groups when food is abundant but survive in smaller groups or alone when food becomes scarce. The size of a gorilla group cannot fluctuate with respect to food availability but the stable, cohesive social group perhaps offers other advantages. For example, silverback gorillas consistently defend their group when faced with a perceived threat but such behavior is rarely shown by male chimpanzees.

Western lowland gorillas living in tropical forest are in a much more complex and demanding habitat than that of the mountain gorillas of the Virungas. In the latter few foods (with the exception of bamboo shoots) show seasonal changes in abundance, and differences in the distribution of food plants are generally closely linked to altitude. Such a habitat presents few intellectual challenges in terms of finding food and contrasts strongly with tropical rainforest which has an enormous diversity of plants, heterogeneous distribution of plant species and complex rhythms of fruit production, creating constant changes in the quality, quantity and location of food. The ways that lowland gorillas have found to cope with these challenges may provide new insight into the ecological and behavioral adaptability of the genus *Gorilla*. We can only speculate about the adaptive strategies adopted by human ancestors, but with continued study of sympatric chimpanzees and gorillas in the tropical forests of the Lopé, perhaps such speculation will become more informed. ■

GRANT SPOTLIGHT

The grant program, the major purpose of the L.S.B. Leakey Foundation under the guidance of the distinguished Science and Grants Committee, depends upon public support for its success. Every penny of your contribution dollar directly supports the grant awards.

Russell Ciochon *$2,000 funded*

ASPECTS OF PRIMATE EVOLUTION IN ASIA AND AFRICA

Dr. Ciochon will be completing the research and write-up of a number of ongoing projects concerning the evolution of primates in Asia and Africa.

Paul A. Mellars *$1,500 funded*

ORIGINS AND DISPERSAL OF MODERN HUMANS: SYMPOSIUM

Dr. Mellars will assist with the organization of a research symposium to be held in Cambridge, England, during March, 1987. About 40 archeologists, physical anthropologists and scientists in other relevant fields from around the world will participate.

Kathe Bjork *$1,994 funded*

PARASITES, DISEASES AND BEHAVIOR OF BABOONS, *PAPIO ANUBIS*, AT GOMBE

There are three objectives for this research at Gombe Stream Research Center in Tanzania: 1) to survey intestinal baboon parasites, 2) to determine intra- and intertroop variation in parasite ova emissions according to age, sex, social and reproductive status, and 3) to begin a pilot study on causes of mortality in Gombe baboons.

Nadine Ruth Peacock *$6,000 funded*

ENERGY EXPENDITURE AND REPRODUCTIVE FUNCTION IN AFRICAN WOMEN

Dr. Peacock will test the hypothesis that high levels of energy expenditure in daily work can suppress reproduction function by studying two low-fertility foraging populations in the rainforests of Central Africa. A second aim of her research is to determine the prevalence of venereal infection and other gynecological pathology in these populations to assess the contribution of such variables to fertility patterns.

Francis H. Brown *$1,000 funded*

OXYGEN AND CARBON ISOTOPE ANALYSIS OF FORAMINIFERS IN THE INDIAN OCEAN

Dr. Brown and his associate, Dr. Andrei Sarna-Wojcicki, will carry out oxygen and carbon isotope analysis from a deep sea core (DSDP231) in the Gulf of Aden. This analysis should provide paleoclimatic information that can be correlated directly by means of tephra (volcanic ash) layers to stratigraphic horizons at early hominid sites in East Africa, accurately placing early human fossils and related biota into a global climatic context.

Kathlyn M. Stewart *$1,200 funded*

FISH REMAINS FROM BEDS I AND II, OLDUVAI GORGE

Ms. Stewart's doctoral research at the University of Toronto is concerned with the investigation of fishing as a subsistence strategy in Pleistocene-Early Holocene East Africa. The beds at Olduvai present a unique and well-documented context within which to investigate some of the earliest archeological evidence for fish utilization in Africa. The fish remains will be analyzed in terms of paleoenvironmental change, dietary contribution, and procurement and processing strategies.

Christopher Boehm *$1,000 funded*

VOCAL COMMUNICATION OF *PAN TROGLODYTES*

Dr. Boehm's aim is to explore the use of a novel two-way methodology in studying vocal communication in the Kasakela chimpanzee community at Gombe, Tanzania. Video and audio recordings are being made of two subgroups as they communicate over long distances, with research focused on understanding the "pant hoot." These complex calls will provide a specific and substantial basis for developing hypotheses on the evolutionary development of human language.

Britt Bousman *$1,974 funded*

PREHISTORY AND PALEOENVIRONMENTS IN SOUTH AFRICA

This project is for soil analysis and sampling at Middle Stone Age (MSA) sites. Research on the pollen and thermoluminescense dating will be done. The single sample of Hughdale Basin pollen is very similar to Holocene pollen samples, rather than Late Pleistocene, from nearby Blydefontein Basin. This suggests that the Hughdale Basin pollen is from the Last Interglacial in the Late Pleistocene.

Dennis Etler *$1,500 funded*

JOINT CHINESE/AMERICAN RESEARCH ON FOSSIL PRIMATES FROM THE LUFENG SITE, PRC

The purpose of the project is to assess the phylogenetic affinities of *Laccopithecus robustus*, a recently discovered gibbon-like hominoid from the Late Miocene Shihuiba fossil ape site in Lufeng County, Yunnan Province, PRC. The research team will be led by Dr. John G. Fleagle of SUNY, Stony Brook, and Dr. Pan Yuerong of the Academia Sinica, Beijing. Mr. Etler was asked to participate because of his fluency in Chinese, both written and spoken.

Hartmut B. Krentz *$2,000 funded*

POSTCRANIA CERCOPITHECOIDEA FROM ETHIOPIA

Mr. Krentz will compare the extinct cercopithecine postcrania from Kanjera, Olduvai, Olorgesaile and Koobi Fora with those from the Shungura Formation, Ethiopia. Primate fossils from Shungura represent the largest collection of Plio-Pleistocene cercopithecoids in Africa.

Mary E. Rogers *$3,000 funded*

THE FEEDING ECOLOGY OF LOWLAND GORILLAS IN GABON

Dr. Rogers will study the diet of lowland gorillas in Gabon, comparing it with that of mountain gorillas. The project is part of a general effort to understand the biology of our closest relatives, the African great apes.

J. Peter Brosius *$1,662 funded*

SURVEY OF PENAN FORAGERS, SARAWAK, EAST MALAYSIA

Mr. Brosius will make an intensive study of the Penan Gang, Sarawak. Data to be collected include: 1) basic census with genealogical information, 2) linguistics, 3) collection of settlement sequence, 4) hunting, 5) social organization, 6) oral histories, and 7) the nature of and recruitment to headmanship.

John Bartheleme *$1,750 funded*

ARCHEOLOGY OF THE LAKE MAGADI BASIN, KENYA

Dr. Bartheleme's project will focus primarily on the location and excavation of Middle Stone Age sites in primary or minimally disturbed context with associated well-preserved faunal remains. Time will be devoted to a systematic survey of the sedimentary basin and surrounding volcanic highlands. ■

FELLOWSHIPS

Great Apes Fellowships Announced

The L.S.B. Leakey Foundation and Wildlife Conservation International (WCI), the worldwide conservation program of the New York Zoological Society, have announced the recipients of the second annual International Fellowships for Great Ape Research and Conservation. These awards amplify and extend a smaller fellowship that the Leakey Foundation launched in 1984 to encourage the establishment of new field research sites. Through WCI's co-sponsorship, the scope of the fellowships has been broadened to emphasize conservation as well as establish new field sites for research.

The new fellowships have been awarded to Christophe Boesch of the Institute of Ethnology, University of Zurich, and to John Michael Fay, a Ph.D. candidate in anthropology at Washington University, St. Louis, Missouri. Dr. Boesch will explore the cooperative and food-sharing behavior of chimpanzees in Tai National Park, Ivory Coast, West Africa, focusing on mental maturation, hunting skills, social structure and the mechanisms of complex cooperative actions. The future of chimpanzees in the wild is highly threatened by tropical rainforest destruction.

Mr. Fay's project, based in the Central African Republic, is a comparative ecological study of western lowland gorillas in virgin and regrowth forests. Mr. Fay, who is a botanist as well as zoologist, will analyze vegetation and habitat as he surveys gorillas. The project, a first on many scientific fronts, will provide the scientific rationale for establishment of the proposed Dzanga-Sangha Sanctuary/Dzanga-Ndoki National Park.

Foraging Peoples Fellowships Awarded

A Fellowship for the Study of Foraging Peoples has this year been awarded by the L.S.B. Leakey Foundation to P. Bion Griffin of the University of Hawaii. Dr. Griffin plans an on-the-ground survey of selected islands and locales of Southeast Asia to study extant groups of hunter-gatherers. The survey is divided into two parts, one concentrating on the forested portions of Sumatra and nearby small islands, the other on visits to the Andaman Islands, Halmahera and perhaps Kalimantan.

Another such fellowship has been given to Kim Hill and A. Magdalena Hurtado of the University of Utah. Drs. Hill and Hurtado plan to continue their research on foraging peoples in lowland South America. (See *AnthroQuest* Number 36.) They plan to collect basic quantitative behavioral and demographic data during the dry season for at least four groups in Peru and Venezuela. They also hope to produce a map of all known foraging populations in South America. ■

New Fellows

The L.S.B. Leakey Foundation is honored to welcome the following new Fellows:

American Can Company Foundation, Greenwich, CT; Heidi Betz, San Francisco, CA; Edwin C. Cohen, New York, NY; Mr. and Mrs. J.E. Coleman, Modesto, CA; Linda DiSante, Honolulu, HI; Bob Steloff, Los Angeles, CA; Elaine McKeon, Hillsborough, CA; General Atlantic Corporation, New York, NY; Margo G. Walker, Glen Cove, NY; Mary Lou Walters, Denver, CO; Cynthia Wilford, La Mesa, CA; David Rockefeller, New York, NY; Robert Brownlee Foundation, San Jose, CA; Mr. and Mrs. James F. Buckley, Jr., San Francisco, CA; and Mr. and Mrs. John Crichton, San Francisco, CA.

IN BRIEF

Query

For a book I am writing on Dian Fossey, I would appreciate hearing from members who have corresponded with Dr. Fossey or might have tape recordings of her talks or lectures.

Thank you.

Harold Hayes
1135 N. Bundy Dr.
Los Angeles, CA 90049

Stones & Bones

The Leakey Foundation has sent a Stones and Bones Study Kit to the University of the Western Cape, an autonomous college for all races in South Africa.

The kit, which comprises a study program of scientific materials including written lessons, television lectures and artifacts, was created some years ago by the Foundation and is now used widely in secondary schools and colleges throughout the United States and in Australia.

The program sent to Western Cape is the first to be used on the African continent, although many of the skulls and fossil bones employed were discovered in South Africa.

La Brea Update

In our last issue, Winter, 1986, Dr. Fred Heald wrote of the paleontological finds at Rancho La Brea in Los Angeles. Since then, excavations for a Japanese art pavilion near the tar pits unearthed a totally new group of fossil mammals, forcing the construction of the new museum to be shut down for a period of time to allow scientists to dig. Included in the new fossil mammals is a series of *Capromeryx*, an antelope-like animal, small and delicate. Also turned up were more remains of the Imperial mammoth. ■

BOOKS

CEREBRAL AGING AND DEGENERATIVE DEMENTIAS, edited by G. Pilleri and F. Tagliavini. Brain Anatomy Institute, Waldau-Bern, Switzerland, 1984. pp 287. *Gratis*.

This publication of the Hirnanatomische Institut at Waldau-Bern, Switzerland, is twice deserving of a review, not only because it is a compendium of authoritative articles dealing with what is currently known about the dementias, but also because, as a private publication, it would not come to one's attention through commercial advertising. The volume, attractively printed on heavy coated paper, can be obtained *gratis* by writing the senior editor at the above cited address.

In the foreword the editors speak to the importance of the subject matter of this volume, pointing out that, at present, 10 percent of the human population over 65 years of age suffers from some form of dementia.

The highly technical contents of the book are divided into four parts focusing principally on (1) clinical, (2) morphological, (3) anatomico-biochemical, and (4) etiopathogenetic aspects of various dementias.

More and more the possibility is beginning to loom that many of the so-called age-related diseases of the nervous system may not be so much a matter of aging as an invasion of the brain by viruses, environmental toxins, and other substances. Mention was made in the introduction of the prediction that by the year 2025 the number of people over 60 years of age would exceed well over a *billion*. Concurrently, given present statistics, the number of people with senile dementia, Alzheimer's disease, and other age-related conditions will be staggering. It is the opinion of some pundits that, in the past, nature has put people out of commission just about the time that they are beginning to acquire wisdom! They attribute some of the world's problems to the fact that society has had to count on relatively young people who must do-or-die before the age of 40 or 50. Hence, if there is a chance that aging might bring the wisdom for meaningful survival of humanity and the rest of the world, there is the need to proceed with all haste in attempting to learn how the brain could better protect itself and cleanse itself of foreign substances. Such knowledge might be crucial for the next step in human evolution.

Paul D. MacLean, M.D.
National Institute of Mental Health
Bethesda, Maryland

OPPORTUNITIES

Essay Competition

The Phillip V. Tobias Essay Prize of the Institute for the Study of Man in Africa was established in 1985 in honor of Professor Tobias, through whose efforts the Institute was established, and in recognition of his standing as a scientist of world repute and his contributions as an academic leader and humanist. He is currently professor of anatomy and director of the paleoanthropology research unit of the University of the Witwatersrand, Johannesburg, South Africa. He is also a member of the Leakey Foundation Science and Grants Committee.

The theme for this year's essay competition is EARLY HOMINID EVOLUTION IN AFRICA. Submissions approximating 6,000 words in length are accordingly invited and should arrive not later than June 30, 1987. These should be in English of adequate literary style and should be typed in double space. They should present the results of original research or of critical reappraisal, and should constitute a significant contribution to current debate on the topic.

A prize of $1,000 will accompany the award and the Institute will seek to facilitate publication of the essay in an appropriate journal.

Submissions and enquiries to: The Secretary, The Institute for the Study of Man in Africa, Room 2B10, University of the Witwatersrand Medical School, York Road, Parktown 2193, Johannesburg, South Africa.

Grants for Primate Research Available

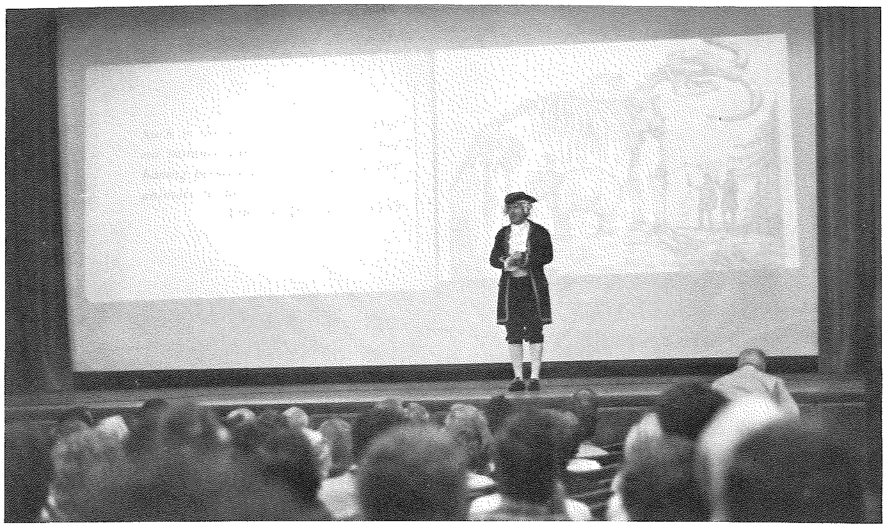
Funding for studies in the wild for researchers connected with a university or institution are available. The researcher must be willing to use volunteers and apply one year in advance. Send for guidelines. Foundation For Field Research, 787 South Grade Rd., Alpine, CA 92001.

In Remembrance

With deepest regret, the Leakey Foundation announces the death of Gertrude Brawner Ralphs in Honolulu on February 9, 1987. A staunch member and Fellow of the Foundation for many years, Trudy attended all the lectures and symposia that she could and even several annual meetings. Her family spoke of her as a globe trotter and bon vivant; she was that but a great deal more to her many friends in the Foundation. Her fight against cancer during the last several years was a model of graceful courage. We miss her.

continued from page 1

WITH APOLOGIES TO JEFFERSON



During Dr. Paul Martin's address at the Leakey symposium on extinctions, he was suddenly interrupted at the back of the auditorium by a stentorous voice crying, "Stop! Stop! This is a travesty!" What appeared to be a reincarnation of the famous early American stomped down the aisle and onto the stage to address the startled audience:

"Fellow citizens, you know me as your President Thomas Jefferson. But I must protest the very idea of extinctions. It is blasphemous! Blasphemous! To think that God, in His infinite wisdom, would make a link in nature's chain so weak that it could break is blasphemous.

"You just wait, my fellow citizens. When Lewis and Clark finally get their expedition going out west – and I don't mean just west to Ohio but away across the Mississippi River to unknown lands – they will find – and you mark my words – they will find the woolly Mammoth!"

Later, having swapped his 18th century clothes and wig for today's more mundane garments, the presenter of this woolly (though still popular in some circles) point of view emerged in reality as Ned Munger, trustee and past president of the Leakey Foundation. And, obviously, an actor *manqué*.

THE MEANING OF ICE AGE EXTINCTION

Paul S. Martin
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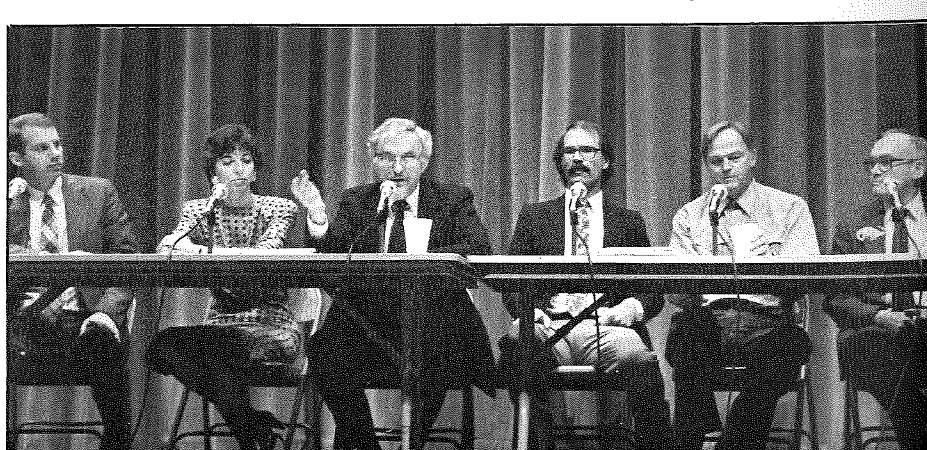
University of Arizona
Tucson

Extinction has long been viewed as much less remarkable than the evolution of species, and until recently the subject suffered neglect. Given the billion year history of life on our planet and the short half-life of most species, it is no surprise to find that very few of the species that have ever lived on earth are still here. Even during times of minimal environmental stress, one expects a steady, albeit low level loss of species. It is worth recalling that the very concept that there was any extinction of species was denied at first. In his *Notes on the State of Virginia*, written in 1781, Thomas Jefferson, the father of American paleontology, voiced his doubts:

"The bones of the Mammoth which have been found in America, are as large as those found in the Old World. It may be asked, why I insert the Mammoth, as if it still existed? I ask in return, why I should omit it, as if it did not exist? Such is the economy of nature, that no instance can be produced of her having permitted any one race of her animals to become extinct; of her having formed any link in her great work so weak as to be broken."

With Lewis and Clark's exploration of Oregon, it became apparent that no living elephants still lurked on the Pacific coast, and the fact of extinction, if not all of its philosophical and religious connotations, came to be accepted.

The Ice Age of the last two million years was a time of environmental instability, and a good deal more than simply background extinction might have been expected. Along with such dramatic changes as the ice advance, sea-level retreat, and worldwide vegetation shifts that accompany the Ice Age climatic pulse, we learn that there was severe loss of large animals. Woolly mammoth, woolly rhinoceros and giant deer lived in Eurasia. North America supported a much larger fauna soon to go extinct, among which were proboscideans of several species (including



Drs. Steven Stanley, Adrienne Zihlman, Irven DeVore, moderator, John Sepkoski, Paul Martin and Ernest Lundelius.

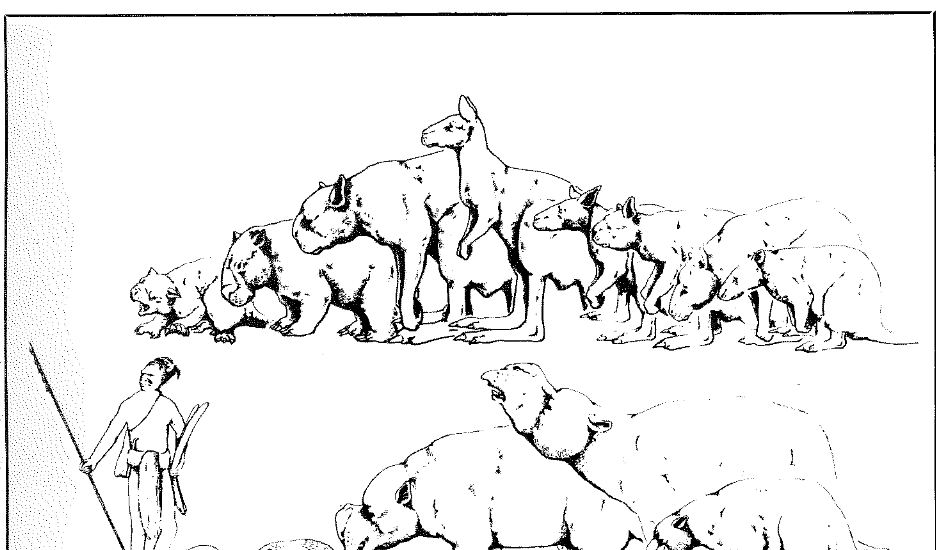
mastodonts), horses, camels, ground sloths and glyptodonts. In addition to these, South America harbored two bizarre orders of mammals, the notoungulates and the litopterns. Even Australia, famous for its peculiar fauna of marsupials, had a weird megafauna of giant kangaroos, giant wombats, a giant ground lizard or "dragon," and the diprotodonts, which were rhinoceros-like beasts with strange snouts and small feet. In mid and low latitudes, the world's oceanic islands supported strange endemic faunas, often with very large and robust flightless birds, some comparable in size to the elephant birds of Madagascar and the moas of New Zealand. When extinction struck, over half the large mammals of the Ice Age world were seen no more.

Most of these extinctions occurred in the last 40,000 years. We know this because of the faunal chronologies built from radiocarbon dating, a method whose development won Willard Libby the Nobel Prize. The radiocarbon revolution which began fifty years ago has vastly enhanced our knowledge of the last Ice Age. To be sure, major extinction events occurred earlier; the most sweeping losses happened at the end of the Permian 245 million years ago. These and other mass extinctions may well have been catastrophic (occurring in less than 1000 years). Yet, it is only during the last 40,000 years that, thanks to radiocarbon dates, we can hope to determine to within a hundred years or even less just when a given species met its fate. The presence of the more common Ice Age mammals can be traced century by century up to a time when, at least locally, they disappear from the view of the paleontologist.

Irven DeVore and Paul Martin.

The radiocarbon chronologies need to be greatly expanded. This is possible now that accelerators have been added to the tool list of the paleontologists. Bone collagen samples too small to be measured by the standard beta counters of radiocarbon laboratories will be sufficient for accelerator measurement.

Based on what we know at present, it appears that both the chronology and the intensity of extinction vary from one part of the globe to another. In parts of Europe and Asia, Ice Age extinction began so gradually that most paleontologists have found little of interest in the local pattern. Woolly mammoth, for example, fade from England and China around or soon after 20,000 years ago. Woolly mammoth, woolly rhinoceros and several other large species that were common earlier are absent from most, if not all, European faunas 15,000–10,000 years old. During most of this time, the North American megafauna still flourished with no hint of impending crisis.

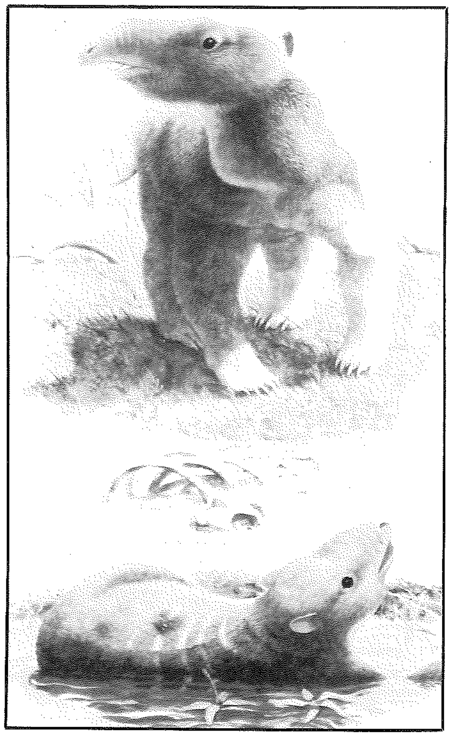


Family portrait: Australian extinct megafauna and hunter.

From Nevada to west Texas, thanks to some 33 radiocarbon dates, it is now apparent that at least up until 11,000 years ago, Shasta ground sloths, browsers of tropical origins, occupied certain dry caves between elevations of 300 and 2000 meters. So did Harrington's extinct mountain goat, a grazer of boreal origins that reached western North America fairly late in the Ice Age. Shasta ground sloths and the extinct mountain goats disappeared from the Grand Canyon of Arizona concurrently, judging by several dozen radiocarbon dates on horn sheaths of the goats. The extinct ground sloths and extinct mountain goats originated in very different climates and environments and, if a gradual climatic shift was involved, one might be expected to disappear independently of the other. In addition, the radiocarbon clock shows that the saber tooths of Rancho La Brea also succumbed around 11,000 years ago. The short-tailed, dagger-toothed "cats" (not truly felids) sought easy prey. Their extinction might be expected in advance of that of the large herbivores if the latter were gradually declining. Under a blighted environment with fewer large herbivores remaining to provide carcasses, the loss of food supply should be felt more severely by the large carnivores. They should succumb first. If they did, it was by a few hundred years only, judging by the synchroneity apparent in my assembled radiocarbon dates on the last ground sloths, extinct mountain goats and saber tooths. It is possible that the extinction of the three species was coeval.

At this point, it should be mentioned that during the last Ice Age and its aftermath when the large-animal extinctions occurred, there was no comparable loss of life in the oceans. No whales, sharks, clams or marine plankton are seen to have disappeared along with the continental mammals. On the continent, the fossil record of plants, fresh water and terrestrial invertebrates, fish, amphibians and smaller reptiles is also unexceptional. We would not suspect that there was a catastrophe among large mammals during the last 40 millennia if the only known fossils were of aquatic organisms.

Some species extinctions among the small mammals were too few to clearly exceed background level. North America had over 200 species of small mammals in the last 20,000 years and lost less than 10 percent of them. In comparison, in only a few millennia North America lost over three-quarters of its species of *large* mammals, here defined as those over 100 pounds (44 kg) adult body weight. The large mammals dropped from 79 to 22 species, a bigger loss than in all the rest of the previous three million years combined. Some birds disappeared too, mostly scavengers or commensals, as various vultures, eagles, hawks and cowbird types that might be expected to have been affected by overall trophic collapse of the megafauna. Thus, the end of the Pleistocene was not a time of mass extinction with the Grim Reaper indifferently scything down a variety of types of animals and plants from many phyla. Extinction was remarkably selective. On continents, catastrophe struck only two guilds: the large herbivores and the large carnivores. What (or who) was responsible?



Australian Diprotodon.

If it was climate, direct fossil evidence of the cause has escaped us. Climatic change by itself is not enough to explain the different intensities of extinction on different continents (heavy in America and Australia, light in Asia and Africa). The pattern also reveals that mostly large, not small, animals were lost, and that there was a peculiar chronology of extinction as revealed by radiocarbon dates, with Australia affected before America, and the latter affected long before Madagascar and New Zealand. What we have is a case of selected extinctions of variable intensities and distributions. Unlike the end of the Cretaceous as visualized in the asteroid model with three months of solar blackout and and ecocidal apocalypse, Ice Age extinctions were time transgressive.

The only event unique to the Late Pleistocene which could conceivably track the regional pulse of extinction outlined above is the deployment of prehistoric people. Their exodus out of Asia can be detected in Australia before America, and in America before Madagascar. The continents or island continents that suffered severe extinctions did so during or after the time of initial human colonization. Africa and Asia, the continents of human origin, were not as severely affected. Imagine the fate of the large mammals of America when they were first exposed to the big game hunters of the Paleolithic. The invaders were among the most skillful outdoorsmen the world has ever seen, with many millennia of prior experience hunting in the steppes and tundras of Eurasia. Until some new hunting taboos or intertribal boundaries could be established, the large animals of the virgin continent were subject to the sort of overkill European seafarers inflicted on previously unhunted Steller's sea cows and nesting flightless sea birds such as the Great Auk and Labrador Duck, with all too familiar results.

This view of the first humans destroying successive gardens of Eden in their exodus out of Asia does not sit well with all anthropologists. Modern hunting-gathering people, such as the Bushmen of Africa and Australia and the Eskimos of the northern latitudes, do not inevitably overhunt their prey and some are not even dependent on meat as a resource. Ethnohistorians, such as Calvin Martin, write of a sacred relationship between hunters and large animals mediated by shamans prior to the secularizing contact with western societies when shamans were "defrocked." Whether or not such cultural wisdom existed, little or no important extinction is seen in the fossil record of North America in the last 10,000 years. Apparently, prehistoric Americans enjoyed the sort of ecological stability most of us would dearly love to attain in our present effort to slow the pulse of modern extinction.

Presumably, potential cultural restraints and the determinism known to closed societies are soon forgotten when a hunter's paradise, a new and uninhabited continent or tropical island, is discovered and is found to be free for the picking. In this respect, our present dilemma of technology outrunning taboo, and extinctions on the rise, may not be vastly unlike the time when hunters first discovered America in their spread across the globe.

What I suggest is that toward and after the end of the last Ice Age two major continents and innumerable oceanic islands previously unoccupied by *Homo sapiens* were overrun, each in turn. The timing and intensity of human arrival can be detected by losses of potential prey, in particular by loss of large mammals, no less than by the appearance of artifacts. Given the confines of what inevitably became for them a closed system, progeny of the invaders learned, indeed had to learn, to regulate their hunting impact. The development of intertribal boundaries, which each group feared to penetrate, helped to prevent further overkill. The invaders overhunted only in the first few years of colonization when easy prey was still abundant, tribal boundaries had not yet been established, and any taboos could be safely ignored. The exact circumstances will never be known.

The seemingly incredible notion I have defended, that prehistoric people obliterated hundreds of species of large mammals (and even more species of smaller animals as oceanic islands were populated) in a very brief moment early in the colonization of the globe, will serve to explain what happened only if the local intensity and chronology of extinction closely tracks the pattern of human dispersal. Thus we return again to radiocarbon dating. The model is refutable; the destruction of giant deer ("Irish elk") evidently preceded known human arrival in Ireland, and thus illustrates such a refutation. But unless many more such refutations can be developed, the concept of global overkill will persist as a simple solution to a unique pattern of extinction. Neither climatic change nor any other natural phenomenon seems to account satisfactorily for the pattern of Ice Age extinction seen only at the end of the last Ice Age. What is the meaning of all this? It would seem that the end of this period saw the start of mass extinction without asteroids, the man-made apocalypse prophesied by our modern shamans – Paul Ehrlich, Edmund Wilson, and Evelyn Hutchison, to name a few.

THE PLEISTOCENE MAMMALIAN CRISIS: HABITAT DESTRUCTION AS AN EXTINCTION MECHANISM

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The rapid extinction of a large number of mammalian taxa at the end of the Pleistocene glacial epoch occurred on all continents. The chronology of the extinction events varied somewhat with the glacial and climatic history of each land mass. Several factors have been suggested as the cause of these extinctions including disease, introduction of exotic species, climatic change and human overpredation. The latter two factors have been most intensely studied and debated in recent years. This report makes a case for environmental reorganization due to climatic change as the primary cause of extinction at that time.

The climatic changes at the end of the Pleistocene were among the most extensive and rapid in the earth's history. These resulted in the loss or reduction in size of glaciers all over the world. The melting of the glacial ice caused a rise in sea level and drowning of parts of the continental shelf. Many lakes were either reduced in size or eliminated. There were changes in temperature ranges and rainfall patterns in many parts of the world. The distributional patterns of plants and animals that reflect these climatic changes have been most closely studied in North America, Europe and Australia.

Ernest Lundelius.

The Late Pleistocene extinction in North America resulted in the disappearance of approximately 68 large (> 5 kg) and 35 small (< 5 kg) species of mammals. Seven trophic classes are represented by extinct species but approximately 68 percent were large grazers and browsers. This appears to be the pattern of extinction on other continents as well. The majority of these species disappeared within a period of 2000 years (ca. 12,000 to 10,000 B.P.).

In North America, and apparently in South America, the extinction event closely coincided both with the arrival of humans and with climatic change. In Australia, there is some evidence that humans probably arrived 15,000 years before the major extinctions. On other continents, humans have coexisted with diverse large mammal faunas for long periods of time prior to the Late Pleistocene extinctions. For humans to have been the primary causative agent of extinction in these areas, one must invoke large population increases or significant advances in hunting technology. This model also fails to explain the loss of non-prey animals.

The case for climatic change as the underlying cause of extinction is based on evidence of extensive habitat destruction at the appropriate time. The changes in the distributions of living species alone do not suggest habitat destruction, although they are evidence of climatic change. It is the association within the same deposits of species whose distributions do not overlap today and whose habitat requirements appear to be incompatible that implies the loss of many habitats at the end of the Pleistocene. These "disharmonious" or "intermingled" faunas are generally interpreted as an indication that Late Pleistocene climates were more equable, with less extreme seasonal variation, than the present. Where there are adequate data, these types of Late Pleistocene faunas are known from all parts of the world.

In view of the disparate habitat preferences of these assemblages, the Pleistocene environment was more heterogeneous or "patchier" that that of today. Data from Pleistocene paleobotanical studies support this interpretation. In North America, the Pleistocene spruce forest, which extended farther south, was more open than at present, with a wider variety of types such as herbs, ash, oak and hickory. Some Pleistocene plant assemblages were also disharmonious.

Worldwide, the terminal Pleistocene mammalian extinctions were synchronous with the disappearance of the disharmonious floral and faunal assemblages. This indicates that the reduction in habitat diversity must have played a crucial role in both phenomena.

An examination of fossil assemblages of the last (Sangamon) interglacial presents some evidence as to why these large scale extinctions did not take place at that time. A deposit of Sangamon age from a locality in central Illinois contains the remains of a large terrestrial tortoise. These animals almost certainly could not tolerate the present winters of that region. Pollen from the same deposit indicates drier conditions than the present. Other Sangamon age fossil faunas have disharmonious assemblages of living species. These are all indications of climatic equability during the Sangamon interglacial in contrast to the post Wisconsinan climatic extremes.

The pattern of extinction over the last five or six million years suggests that the extinction events that took place 5, 1.8 and .6 million years ago all coincided with glacial terminations. Periods of deglaciation appear to be times of climatic stress for organisms. These episodes of extinction, almost as severe as the one at the end of the Pleistocene, preceded the arrival of humans in many parts of the globe, and indicate that climatic change alone can be responsible for major extinction events.

THE ROLE OF CLIMATIC CHANGE IN MASS EXTINCTION

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Mass extinctions are episodes of earth history in which a large percentage of the planet's species dies out. Contrary to the popular view, many of these destructive episodes have not been geologically instantaneous, but spread over a few million years. Perhaps their most salient trait is their elimination of large natural groups of species – groups formally recognized as genera, families, orders or other higher taxa.

It is my view that the most important proximate agent of mass extinction – that is, the immediate cause of death – has been climatic change, usually cooling. There is a reason why, *a priori,* we might suspect that this should be so. Temperature is the most important environmental control of the distribution of species on a geographic scale, and mass extinction is a geographic, not a local, phenomenon. Furthermore, since vertebrate animals first populated dry land, they have generally suffered mass extinction at the same time as animals in the oceans. Global climatic conditions, more than any other normal ecological limiting factor, affect land and sea simultaneously.

Nonetheless, over the years, a number of other agents have been proposed as dominant causes of one or more marine mass extinctions. Among these are: changes in the salinity, or salt content, of the oceans; reduction of the level of dissolved oxygen in the oceans; and lowering of sea level, which reduces the area of habitats on shallow sea floors.

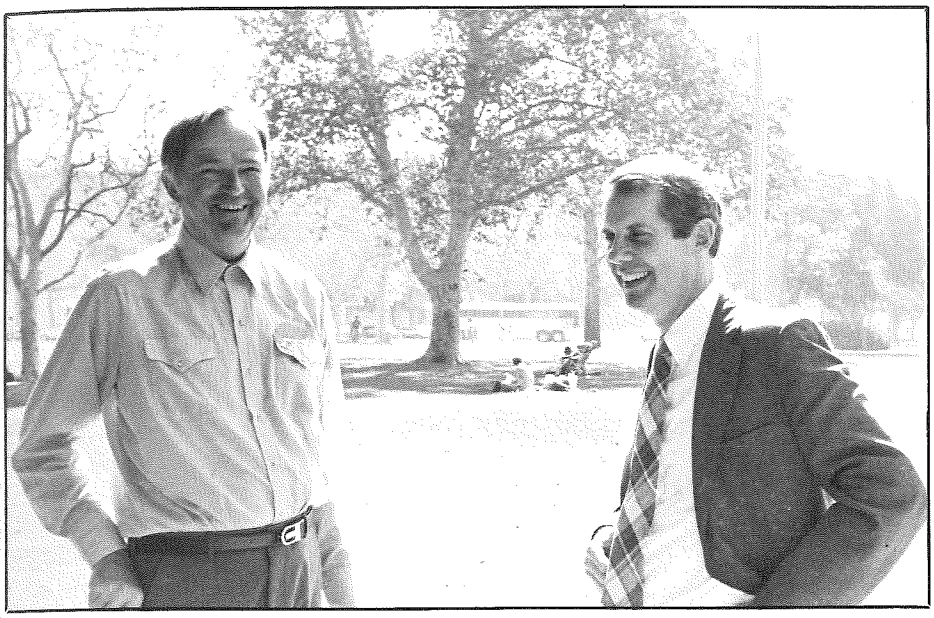
In fact, it's generally agreed that major changes in salinity on a global scale are unlikely.

The problem with reducing oxygen levels is that this can only happen at depth within the oceans. As long as the partial pressure of oxygen in the atmosphere remains more or less where it is now – a likely condition – then stirring by wave action oxygenates the upper 20 meters or so of the ocean, a zone where all mass extinctions have struck heavily.

I could provide a lengthy discussion of the evidence against sea level lowering as an important agent of marine extinction, but will simply say two things. First, narrow areas of sea floor today accommodate huge faunas of shallow marine life. An example is that one that fringes the narrow west coast of the tropical Americas. Here live, quite happily, about 3000 species of shallow water mollusks – sea shells, if you like. The isolated Hawaiian Islands also support a large number of species, many of them restricted to this tiny area. Second, we can now see that many great episodes of sea level lowering in the past did not coincide with mass extinction. Early in Oligocene time, for example, shallow seas spread over much of Eurasia. Then, about 32 million years ago, they rapidly receded, here and throughout the world. No mass extinction occurred. Apparently species that required shallow sea floor were able to survive in the reduced areas of suitable habitat that remained.

When we test the hypothesis that climatic change has been an important cause of mass extinction, the results are much more positive. Many patterns support this hypothesis; many of its predictions are borne out. One of these predictions is that if cooling has been the dominant agent of extinction, then losses should be most heavy in the tropics. The reason is that during global cooling, climatic zones should shift toward the equator. Many species adapted to nontropical climates should be able to migrate equatorward with the zones to which they are adapted. Not so for tropical species. The tropics have no place to go; they and much of their biota will simply disappear.

Now, some examples. I will begin with a relatively recent crisis, one that affected mammals on the land as well as life in the sea. This is the Eocene-Oligocene event, which began about 40 million years ago. It is especially well documented for fossil plankton – minute floating creatures whose preservable skeletons rain down on the sea floor. Some of these were the group known as calcareous nannoplankton, whose spheroidal cells were armored with tiny calcareous plates that have left an excellent fossil record in deposits of the deep sea. The calcareous nannoplankton suffered heavy losses in Late Eocene time. Over a period of about



Paul Martin and Steven Stanley

seven million years, their total number of species in all seas dropped from about 120 to only 40. The fate of these algae is especially important in light of the climatic cooling hypothesis, because ever since the nannoplankton came into being, during the Age of Dinosaurs, their center of distribution has been in the tropics.

The fossil record of another floating group, the planktonic Foraminifera, has been scrutinized in greater detail. These are like tiny amoebas with skeletons. As it turns out, the warm-adapted species of planktonic Foraminifera were hardest hit. Also, the extinctions of these forms were spread over eight or nine million years, and came in pulses. The primary victims were species with spiny skeletons; these are forms that tend to be adapted to warm conditions.

Life on the sea floor also suffered – and, again, there was a bias against species adapted to warm conditions. Mollusks suffered heavy losses in Europe, the Gulf of Mexico, and the Pacific Northwest, and in each area there were especially high casualties in those genera whose center of distribution was in tropical or subtropical zones.

On the land, the mammals suffered two pulses of extinction, each apparently coinciding with one of the pulses of planktonic extinction in the oceans. The first of the mammalian events occurred at the end of the Eocene epoch, about 37 million years ago, and the second during the ensuing Oligocene epoch, about five or six million years later. These events have been documented in the American West. The most conspicuous victims of the second crisis were the titanotheres, which had been highly successful horned animals related to rhinoceroses.

We have powerful evidence of major climatic cooling during this protracted and pulsatile crisis, both in the sea and on the land. This was the time when the deep sea became cold; it has remained so to the present day. The deep sea is now near freezing because sea water is cooled near the earth's poles. Being dense, it then sinks and spreads over the floor of the deep sea. This refrigeration system was not operating early in the Age of Mammals. The poles were warmer then and the deep sea was too. Temperature estimates from isotopic evidence indicate substantial cooling during the Eocene-Oligocene transition.

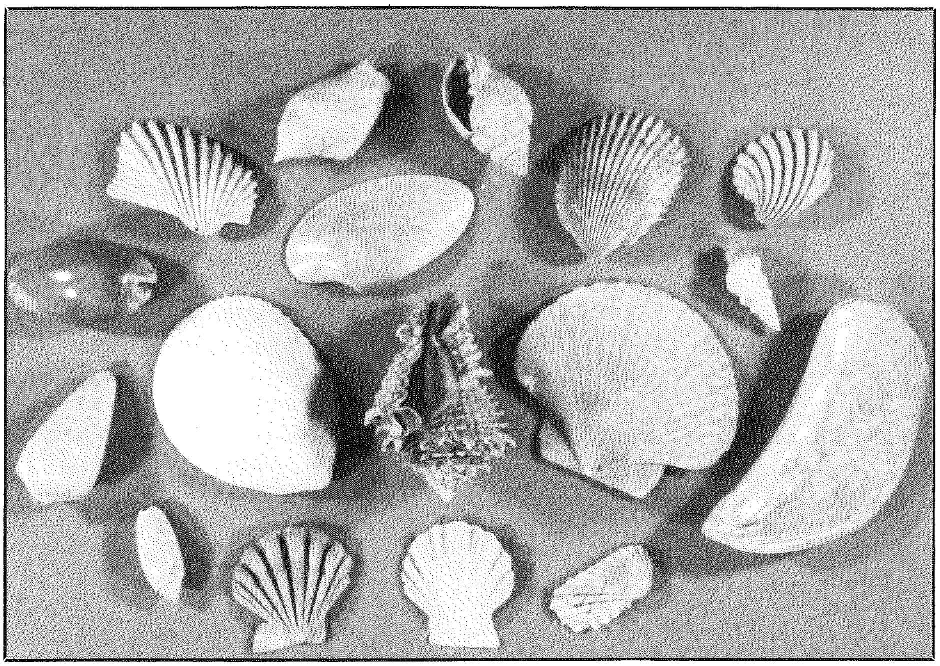
We have solid evidence that climatic changes were occurring simultaneously on the land as in the sea. This comes from the analysis of fossil leaves. In floras of the modern world there is a linear increase with mean annual temperature in the percentage of species with smooth, rather than jagged or lobed margins. When this relationship has been applied to fossil floras, it has yielded a curve for mean annual temperature across the Eocene-Oligocene interval. There were pulses of cooling in many parts of North America and finally the persistence of cool temperatures. This pattern, with minor interruptions, culminated about three million years ago with the onset of the modern Ice Age.

To appreciate the profound nature of these climatic changes one need only contemplate that in Middle Eocene time, before the onset of cooling, southeastern England was cloaked in tropical jungles that have been compared to the modern jungles of Malaysia. England has never been the same since.

Now I want to transport you back much farther in geologic time in order to have a look at earlier mass extinctions, in chronological order. The earliest crisis that has been recognized occurred about 650 million years ago. This event struck the acritarchs, planktonic algae that left an excellent fossil record for hundreds of millions of years. At the time of this very early crisis, primitive multicellular animals were in existence, but they lacked skeletons, and for this reason their fossil record is too incomplete for us to determine how the crisis that decimated the planktonic algae may have affected animal life. It is a remarkable fact that the time when the crisis struck the acritarch algae was a time when glaciers spread over many parts of the earth, one of the most extensive glacial intervals of all time. Certainly we must entertain the possibility that this was no coincidence – that climatic cooling associated with the glacial episode caused the mass extinction.

Now let's move up into the Age of Invertebrates, the Paleozoic era. Late in the first Paleozoic period – the Cambrian – there were three mass extinctions of marine life, the final one occurring at the very end of Cambrian time. The primary victims of these crises were the trilobites – primitive, three-lobed arthropods distantly related to living horseshoe crabs. The three crises have been best documented in North America. This continent in Late Cambrian time sat astride the equator, which means that the trilobites lived in tropical seas. These shallow seas covered almost all of the United States, which lay to the west of Canada. Three times the trilobites diversified and three times they suffered an abrupt extinction. It is easy to see why diversification, or adaptive radiation as we call it, followed each extinction event. With each extinction event, the seas were suddenly depleted of trilobites and there was room for diversification. What we are interested in, however, are the extinction events themselves. As it turns out, they occurred without changes in sea level or general environmental setting.

Two hypotheses have been advanced to explain the trilobite mass extinctions.



Early Pliocene mollusks from Florida, many of which died out as a result of Ice Age cooling within the past three million years.

One is that water masses low in oxygen expanded from great depth in the ocean to shallow settings. The problem here is that shallow settings of the sort inhabited by most of the trilobite species that disappeared will always be oxygenated from the atmosphere by the action of waves. The second hypothesis is that shallow seas underwent sudden cooling. Supporting this idea is the fact that the group that invaded after the sudden extinction event – and gave rise to a new adaptive radiation – was the trilobite family Olenidae. The crucial point here is that the olenids normally inhabited waters that were deep and therefore cool, and also cool waters far from the equator. They are exactly the sort of group we might expect to survive a crisis of global cooling that eliminated nearly all tropical species. I think the case for climatic causating here is a strong one.

Next I want to discuss three great mass extinctions as a group. These took place during the Paleozoic era near the ends of the Ordovician, Devonian and Permian periods. The third of these, the terminal Permian crisis, was probably the most severe mass extinction of all time, perhaps wiping out more than 90 percent of all marine species; it brought the Paleozoic era to a close. In addition, the Permian event was the first mass extinction to strike vertebrate animals on the land. The preceding mass extinction, that of the Late Devonian, took place at about the time when the first amphibians were crawling up on the land. This earlier event did affect one very important vertebrate group, however. It wiped out nearly all of the marine placoderm fishes. By Permian time, amphibians had given rise to reptiles, and the dominant reptile groups already resembled mammals in features of their skulls and locomotory anatomy. In fact, the Late Permian mammal-like reptiles were probably to some degree warm-blooded and may well have had insulating fur. It was Late Permian mammal-like reptiles that seem to have been the first land vertebrates to be victimized by mass extinction.

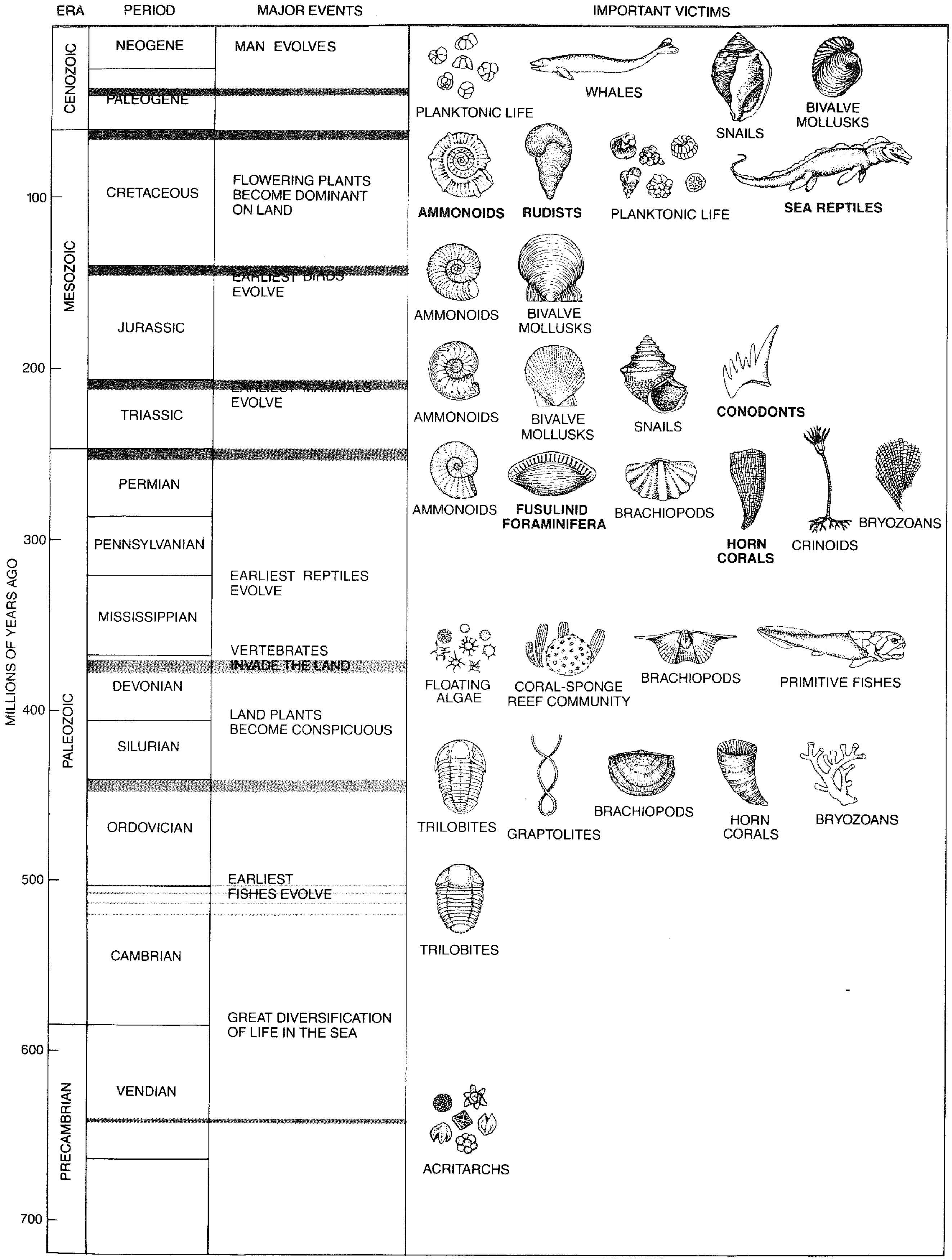
Now let's look at features shared by the three post-Cambrian Paleozoic crises; indeed, they display common themes that command our attention. We see in each of the three crises the familiar tropical bias. Each event, for example, decimated the tropical reef community of the day. Other forms of life also died out, among them groups of calcareous green algae. Calcareous algae today are restricted to warm seas, and their ecological requirements are so minimal that I find it difficult to believe that anything other than climatic cooling could cause their demise.

Another pattern that strongly suggests cooling as the primary agent of extinction in the Ordovician and Permian crises is that, as extinction was occurring, the distributions of various groups of organisms became compressed toward the equator. This pattern of latitudinal compression is exactly what we would expect if cool temperatures were spreading equatorward from high latitudes.

Note that it is implicit in the movement of biotas during extinction that each of the three crises spanned several million years. None of them could have been caused by the instantaneous arrival of a meteorite from outer space. Each extinction event seems to have occurred in a series of pulses. This is true not only for marine life, but also for terrestrial life during the Late Permian event. Mammal-like reptiles underwent several episodes of extinction and recovery in Late Permian time. It has been suggested that these were related to climatic changes that we know were transforming vegetation on the land. At this time the floras that occupied swamps and produced coal were giving way to plant groups adapted to drier conditions. These included the conifers or cone-bearing plants that are familiar to us in the modern world.

Another important aspect of timing has to do with the aftermath of each extinction, when there was an interval during which faunas were unusually cosmopolitan and individual species and genera were spread over large geographic areas. This pattern is well documented for the marine realm, but is quite evident also for the terrestrial fauna of mammal-like reptiles. We can explain such a pattern in either of two ways, each of which is compatible with a climatic cause for extinction. One possibility is that extinction tended to befall species that were narrowly adapted with regard to climate, ones that could not range over a wide range of latitudes. The second possibility is that in the aftermath of the mass extinctions, latitudinal temperature gradients were reduced so that survivors were able to spread far and wide.

We can also see that the aftermath of each mass extinction was an interval characterized by reduced rates of limestone deposition and limited success of organic reefs. Limestone is deposited chiefly in tropical seas, as the accumulation of fragments of calcareous skeletons of marine life. Reduced rates of limestone production suggest cooler temperatures. It is true that reef-building species died out in the mass extinctions, but there is no reason why the survivors should not have flourished unless conditions remained unfavorable for a time. And here I would point to a remarkable fact concerning the Late



from Scientific American

Mass extinctions have struck all kinds of marine life over the past 700 million years, from single-called algae and plankton to huge swimming reptiles and whales. The most famous crisis occurred 65 million years ago at the end of the Cretaceous period, eliminating most marine species at about the time the dinosaurs became extinct on land. In many cases an animal or plant group has been able to recover after a crisis and evolve new species; in other cases the entire group has vanished from the sea (bold type).

Permian crisis. Reefs are unknown from Lower Triassic rocks, which represent about five million years of time following the crisis. But then, in Middle Triassic time, there was a resurgence of reef growth in areas such as southern Europe. And, quite remarkably, the reef builders included the very same forms of calcareous algae that had built reefs in Late Permian time and the very same kinds of calcareous sponges. What could have suppressed these simple forms of tropical life for several million years except unfavorable temperature conditions? I have yet to hear another reasonable possibility.

The most famous mass extinction, the terminal Cretaceous event, ended the Age of Dinosaurs, the interval we formally term the Mesozoic era. This crisis, like the one that brought the Paleozoic era to a close, struck not only on the land but also in the sea. Among the marine victims were a variety of large reptilian sea monsters, including giant monitor lizards called mosasaurs. Again, losses in the oceans followed the standard pattern; they were heaviest in the tropics. And again the reef community was devastated. This time the victims – the dominant reef builders of Late Cretaceous time – were the rudists. These were a strange group of bivalve mollusks that evolved from burrowing clams. They grew upright like corals but their upper shell formed a lid. The rudists went the way of the dinosaurs; they suffered total extinction. That's why tropical reefs today are formed by corals. Other forms of marine life also suffered heavily.

In the North Atlantic, gastropod mollusks – snails – underwent changes that also suggest that cooling occurred at the end of Cretaceous time. The species that had lived in the vicinity of Greenland spread southward so that early in the Age of Mammals they inhabited shallow seas of North Africa, which had been tropical. A similar pattern of migration characterized planktonic Foraminifera. Spiny, warm-adapted species suffered heavy extinction and cool-adapted species migrated toward the equator.

It has also become apparent that many groups of animals began to suffer extinction before the end of the Cretaceous. The rudist reef builders, for example, declined drastically three or four million years before the end of the Mesozoic era. Dinosaurs also experienced a gradual decline. This is especially evident in the relative abundances of species. It is quite clear that during the final two million years of the Cretaceous period, horned dinosaurs – specifically Triceratops – dominated the ecosystem, comprising about three quarters of all large dinosaurs. In other words, we have evidence that, although a sudden event at the very end of the era may have administered the final coup, the ecosystem was already deteriorating – both on the land and in the sea.

As many of you know, a high concentration in uppermost Cretaceous sediments of the element iridium, which is extremely rare on earth, has been taken to signal the biotically devastating arrival of a comet or meteorite from outer space. This cannot be the whole story of the Late Cretaceous crisis. Not only does it appear that an extraterrestrial impact event could be no more than part of the story of the termination of the Age of Dinosaurs, but extensive searching in the rock record has turned up no high concentration of iridium at the level of any earlier mass extinction. It appears that the iridium anomaly is indeed anomalous.

The recent Ice Age has indeed, caused heavy extinction, but mainly in the North Atlantic region and neighboring areas. I have studied major losses of the marine life in the Atlantic Ocean and Caribbean, and others have studied major extinctions of antelopes in Africa at the time when *Australopithecus* was gamboling about. The crisis has been restricted in a real extent because cooling during the recent Ice Age has not been severe in most parts of the world and losses have also been reduced by the fact that temperatures in many areas were somewhat cool and seasonal long before the onset of the Ice Age, about three million years ago.

Humans have survived Ice Age freezing. If you want to *worry*, worry about *nuclear winter*.

Adrienne Zihlman.

THE CASE OF THE VANISHING HOMINIDS

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Africa is the central focus for viewing the pattern of human evolution. It is from Africa that our human lineage arose; it is out of Africa that hominids expanded their range to other parts of the world; and Africa may be the place of origin for the modern species, *Homo sapiens*.

Several lines of evidence lead to these conclusions. First, molecular data show our close genetic relationship to the African apes, the chimpanzees and gorillas. Next, the fossil record has a long time depth in Africa, with human fossils first appearing about 3.5 million years ago and with continuous representatives until recent times. Finally, in no other place in the world do human fossils exist that are as old and as anatomically primitive. Africa is also most likely the place of origin for our own species, *Homo sapiens*. New information on DNA of modern human populations as well as on the fossil record suggests that modern humans lived in Africa some 100,000 years ago, at a time when

TIME CHART

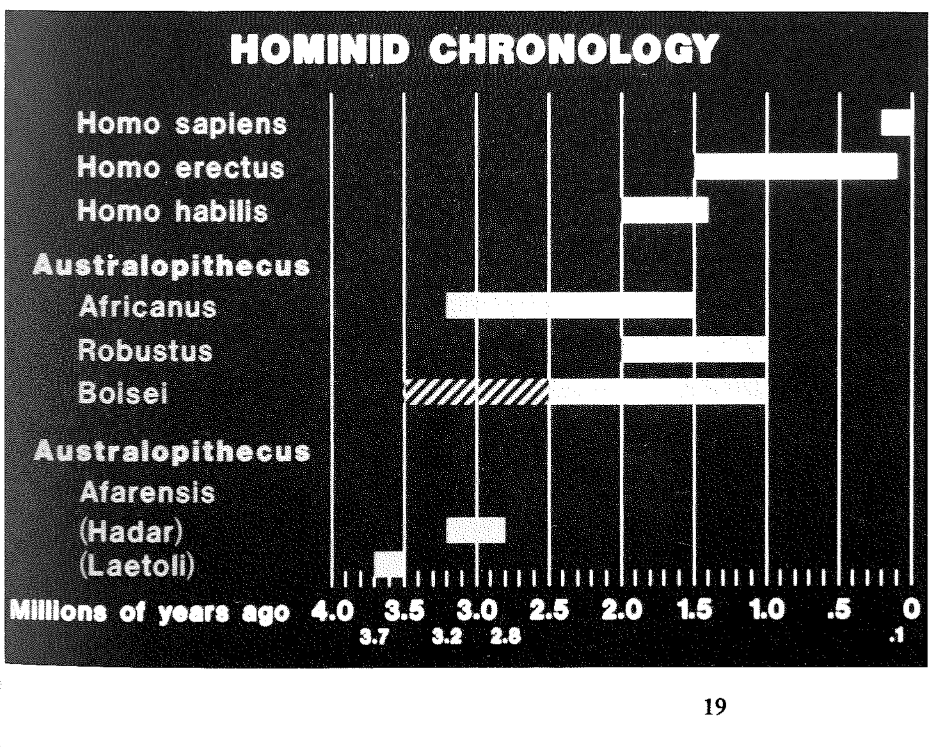
Time (mya)	Events
.01	Domesticated plants and animals
.1	*Homo sapiens* throughout Old World
1.0	Human populations expand out of Africa
1.5	*Homo erectus* in Africa
2.0	Earliest stone tools; possible butchering of large mammals
3.0	Possibly two species of early hominids
3.5	Fossil evidence for early hominids in Africa
5.0	Estimated divergence of human and ape lineages

the Neanderthal populations were surviving in Europe.

How diverse and widespread have hominids been since their appearance almost four million years ago? At most there have been eight species: four of *Australopithecus – afarensis, africanus, robustus, boisei* – and four of *Homo – habilis, erectus, neanderthalensis*, and *sapiens*. Three of these (*A. afarensis, H. habilis, H. neanderthalensis*) may not be valid species if one considers the limited time period in which they lived. The first four species inhabited only East and South Africa between some 3.5 and 1 million years ago. The earliest appearance of the genus *Homo* is in East Africa, first as *H. habilis*, next as *H. erectus*. Only Neanderthal populations like those in Europe and the Middle East have not been found in Africa. Possibly the oldest evidence of *Homo sapiens* comes from southern Africa, from Border Cave.

What happened to all these species of hominids? Did they all become extinct? If so, what does that mean? It's worth noting that over the last three to four million years, the hominid family has not been particularly diverse and the limited diversity decreases with time. The reason for that can be sought in the nature of human adaptation. Hominids are flexible and opportunistic rather than specialized and highly competitive. Perhaps only one hominid line really became extinct – the robust australopithecines. Other species may have been replaced in successive stages, with *Homo* species replacing *A. africanus*.

The extinction of the robust australopithecines may be correlated with climatic change rather than competition with *Homo*. Technological development was minimal for these hominids, and their brain size remained small. With the appearance of *Homo* brain expansion began about two million years ago, and is correlated with technological breakthroughs which suggest more effective utilization of resources. Social breakthroughs based on more elaborate vocal communication and social organization may have also occurred at this time.



PERIODICITY IN EXTINCTION

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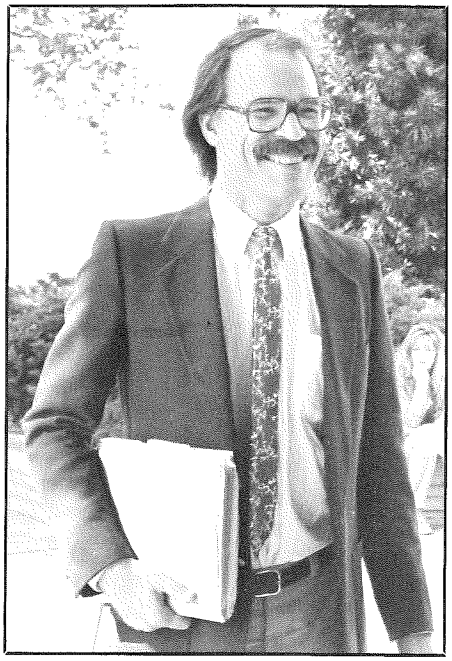
The fossil record tells us that more than 99 percent of all species that have ever lived on earth are now extinct. Yet we know little about extinction, as either a phenomenon or a process. How does a species become extinct? What processes are operative? How commonly are these catastrophic? How do we predict what species will become extinct in a given situation? And, how do we manage the biota to control extinction? These questions are of great contemporary importance as we witness more and more human alteration of the earth's surface with concomitant levels of extinction that are unprecedented in historical times, expecially in the tropics. They are also of great importance as



John Sepkoski.

we face the specter of nuclear winter and attempt to determine what portion of the biosphere could survive such a holocaust. And, on a gentler note, the questions are of major scientific interest as we investigate the 3.5 billion year history of life on this planet and ponder its implications for life elsewhere in the universe.

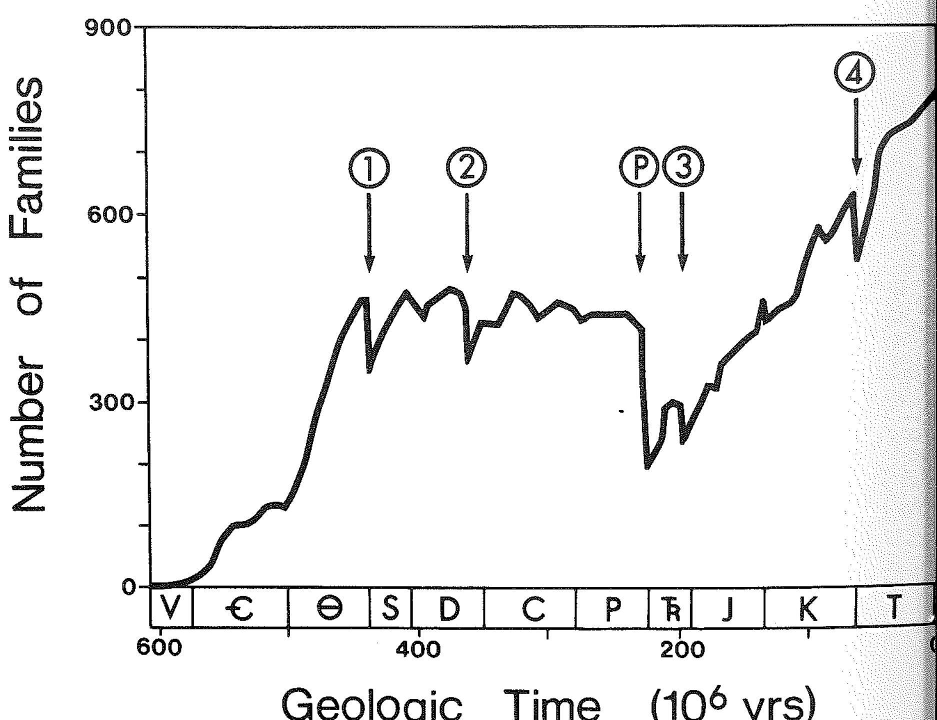
The best known symbol of extinction is the dinosaur. Although these animals were long considered representative of life that was too large, slow and primitive to survive changing times, modern research has demonstrated that they in fact comprised a complex and diverse group that dominated the large vertebrate adaptive zone on land for 150 million years, twice the duration of the "Age of Mammals."

Why dinosaurs became extinct at the end of the Cretaceous period, 65 million years ago, is still being debated, but recent discoveries suggest that their demise may have been catastrophic, induced by the impact of a large extraterrestrial object. This now well-known hypothesis was introduced in 1979 by Luiz and Walter Alvarez along with their colleagues, Frank Asaro and Helen Michel, who found excess amounts of iridium and other siderophilic elements in the boundary clay separating Cretaceous from Tertiary strata in several localities in Europe. Iridium, the densest of all elements, is rarefied in rocks at the earth's surface as a result of transport toward the core during the formation of the planet. It is more concentrated in many meteorites that have not undergone complex geochemical differentiation. The discovery of excess iridium, concentrated to several hundred times normal surface values, at the Cretaceous/Tertiary boundary led the Alvarezes to posit a collision with a large meteorite, estimated from the iridium concentrations to have been around 10 km in diameter. Subsequent discoveries of altered microtektites and shock-metamorphosed quartz in boundary clays have corroborated this hypothesis. Modeling of such a collision suggests that it would have ejected dust from the impact crater throughout the atmosphere, blanketing the earth in darkness for up to three months, freezing much of the surface, and prohibiting photosynthesis and thus primary production. This would have caused starvation of many herbivores and their predators and induced widespread extinction, especially among larger animals with greater food requirements.

Thus, the dinosaurs perished and, along with them, the flying reptiles, most marine reptiles, and many marine invertebrates. In fact, almost 45 percent of the known genera of marine animals, and perhaps 60 to 70 percent of marine species, became extinct at or near the end of the Cretaceous.

These estimates of the magnitude of the extinction come from an extensive compilation of data on the fossil record. The compilation is much like a demographic survey tracing the births and deaths of individuals through old municipal and church records. For over two centuries, paleontologists have been describing fossils, giving them Linnean names, and classifying them into higher taxonomic categories. This information is published in scientific literature throughout the world. I have been endeavoring to track down this information and collate it to provide a data base of the times of origination and extinction of animal taxa, mainly genera and families, throughout their 700 million year fossil record. Most of this effort has been concentrated on the marine fossil record, which is more complete and better studied than its counterpart for terrestrial and freshwater ecosystems. To date, my compilations contain data on some 3500 families and nearly 30,000 genera of fossil marine animals.

The diversity of families in the

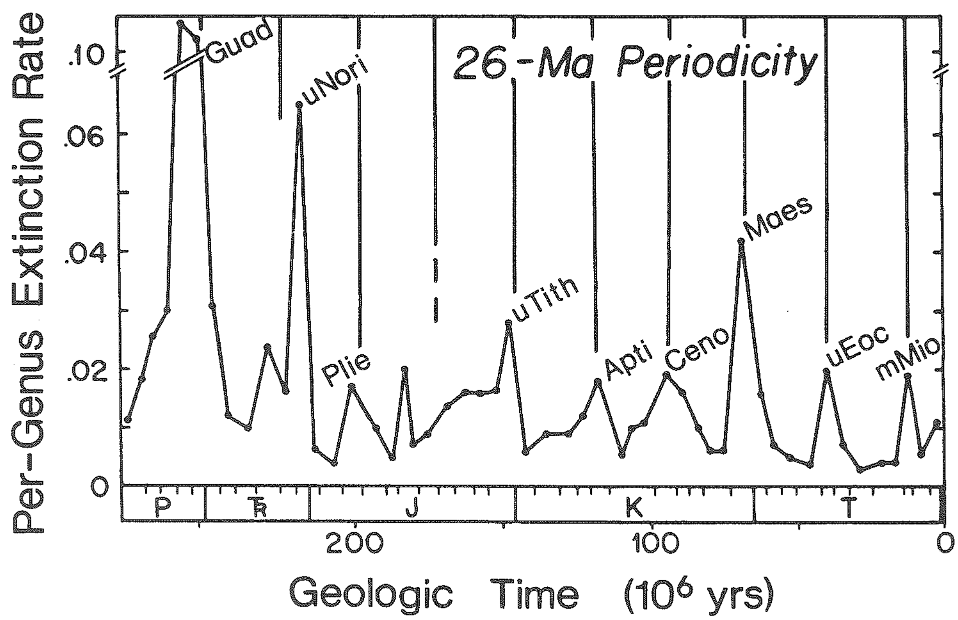


Diversity of marine animals through time. Arrows demark the major mass extinctions, occurring in 1. the latest Ordovician (Ashgillian Stage), 2. Late Devonian (Frasnian), P. Late Permian, 3. latest Triassic (Norian), and 4. latest Cretaceous (Maestrichtian). Symbols along the horizontal indicate geologic systems: "V" = Vendian (or latest Precambrian), "E" = Cambrian, "8" = Ordovician, "S" = Silurian, "D" = Devonian, "C" = Carboniferous, "P" = Permian, "T" = Triassic, "J" = Jurassic, "K" = Cretaceous, and "T" = Tertiary.

oceans through geologic time has increased considerably from the beginning of the Cambrian, 575 million years ago, to the present; this increase has been interrupted several times by major declines. These declines are the major events of mass extinction. The mass extinction at the end of the Cretaceous eliminated 17 percent of animal families in the oceans. Three other events had comparable magnitudes; these occurred at the end of the Ordovician (440 million years ago), within the Late Devonian (365 million years ago), and near the end of the Triassic (220 million years ago). But all of these pale in comparison to the great mass extinction at the end of the Permian, 245 million years ago; this event eliminated more than 50 percent of families, 80 percent of genera, and perhaps 96 percent of species in the oceans.

These five events are the large mass extinctions in life's history. But there are a number of other smaller extinction events that have occurred rather frequently through geologic time. These events are best observed in data for fossil genera compiled not as diversity but as rates of extinction in each sampled interval of time. Several years ago, my colleague, David Raup, and I were examining the timing of these smaller events over the last 250 million years and noticed that they seemed to occur very regularly. This was actually an observation first published by Alfred Fischer and his student, Michael Arthur, in 1977. Raup and I performed a variety of statistical tests on the data and concluded that the timings of the events were almost certainly nonrandom and could best be described by a 26 million year periodicity. Although the periodicity was not perfect, it nevertheless indicated an unexpected regularity in the collapses of the marine ecosystem.

What does such a periodicity imply for the cause of mass extinction? Raup and I interpreted it to mean that the extinction events must have had some simple, ultimate forcing agent that had clocklike behavior. If there had been many independent forcing agents inducing mass extinction, we would have expected a random (i.e. Poisson) distribution in time, and this pattern was clearly rejected by the data. We also concluded that the forcing agent must be physical, since we could conceive of no evolutionary process that could produce periodicity with such a long wavelength. Finally, we thought that if all events were driven by the same ultimate agent,



Per-genus rate of extinction (in units of genera per genus per million years) for marine animals from the Middle Permian to Recent. Labeled peaks correspond to extinction events, which exhibit an approximate 26 million year periodicity over this interval, as indicated by the vertical lines. Labels for the peaks are "Guad" = Guadalupian (Late Permian), "uNori" = upper Norian, "Plie" = Pliensbachian, "uTith" = upper Tithonian, "Apti" = Aptian, "Ceno" = Cenomanian, "Maes" = Maestrichtian, "uEoc" = Upper Eocene, and "mMio" = Middle Miocene. Note that the Late Pleistocene extinction of large terrestrial vertebrates, discussed by Martin and Lundelius, has no counterpart in the oceans, and that the Pliocene-Pleistocene extinction of mollusks, discussed by Stanley, appears as a small, aperiodic rise in extinction rate at the righthand margin of the graph. The points along the time series indicate measured values, computed for 51 stratigraphic stages and substages averaging 5 1/2 million years in duration.

perhaps the causal chains leading to mass extinction might be similar for all events. This last inference leads back to the dinosaurs: If their extinction resulted from the impact of a large extraterrestrial object, perhaps the victims of other extinction events met their demise similarly.

This speculation has led to considerable scientific activity searching for evidence of impacts associated with other extinction events and constructing models of astrophysical phenomena that could generate periodic impacts. Workers have speculated that the periodicity might have been caused by the known long wavelength oscillation of the solar system about the galactic plane or by an undiscovered tenth planet with a highly inclined orbit that could periodically scatter comets toward the sun. The best-known speculation is that the sun might have a small, unobserved companion star, dubbed "Nemesis," in a very elliptical orbit that takes 26 million years to traverse; most of the time this companion would be far from the sun, but every 26 million years or so it would move through the Oort Cloud of comets, scattering up to a billion into the inner solar system, with an average of 25 colliding with the earth over a one to three million year interval.

To date, there is no independent evidence that the sun has a binary companion. In fact, there is scant evidence that any mass extinctions other than the end-Cretaceous and perhaps Late Eocene (40 million years ago) events are associated with impacts. It may be that the whole line of reasoning linking extinction events to impacts is incorrect. Most of these events over the last 270 million years have been rather small and nearly equal in magnitude; only three large events, at the ends of the Permian, Triassic and Cretaceous, are large, and these stand out like statistical outliers in comparison to the others. This might suggest that the impact at the end of the Cretaceous was coincidental, that conditions were already leading up to a "normal," periodic extinction event and that a random impact merely aggravated the situation. Or perhaps this one impact was unusual but not coincidental.

One might speculate that the damaging agent of comet showers was not so much impact as dust left by the billion comets in the space of the inner solar system; some solar radiation might have been blocked by this dust, especially as it became entrained in the earth's atmosphere, causing the climatic cooling that Steven Stanley argues is the proximate cause of mass extinction. In this scenario, impacts of very large comets might have occurred only rarely during mass extinctions, with the end-Cretaceous event being one example.

The bottom line is that we still do not know the ultimate cause of periodic extinction. And, we do not yet know what effects this periodicity has had on the course of evolution. But there is some reason to suspect it may have been profound. Ecosystems are not infinite but are limited by the finite amounts of space and resources available to organisms. In some cases, these resources can be usurped rapidly over geologic time scales, causing the evolutionary system to go into equilibrium with greatly reduced evolutionary rates. An apparent equilibrium can be seen through much of the Paleozoic era. Near the end of the Ordovician, the marine fauna attained a diversity of around 400 families, which was maintained for the next 250 million years, except for the two large mass extinctions. These events diminished diversity and were immediately followed by intervals of rapid evolution that moved diversity back to the previous level. Significantly, during these intervals of rebound, many new taxonomic orders of animals, representing fundamentally new variations upon body plans, appeared in the oceans. This same phenomenon happened on land after the end-Cretaceous mass extinction. Mammals had lived for 150 million years prior to this event in the interstices of the dinosaurian world and had undergone only very slow evolutionary changes. But upon the demise of dinosaurs, they underwent an explosive evolutionary radiation into the new world left in the aftermath of the mass extinction, and, in less than 10 million years, produced approximately 20 new orders ranging from bats to whales and rodents to ungulates. Perhaps we owe our very existence to a comet that struck 65 million years ago.

Some Readings on Extinctions

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To The Editor

Over the years I've gone to a number of Leakey symposia and have never been disappointed – until this past one on mass extinctions. It was okay as far as it went, but to me there was a glaring omission, namely that there's a mass extinction going on right now. (At least that's according to such sources as the Wildlife Federation.)

Mention was made of the disappearance of so many large land mammals roughly 10,000 years ago, and it was speculated that human hunting may have had a hand in it. But not a single word was spoken about all the extinctions from 10,000 years ago to the present, much less the accelerated rate in just the past few decades, much less the momentum that builds daily and will wreak even greater havoc in the future. Some estimate that a species a day is dying out, or, more precisely, is being forced out by human population and habitation. Geologically speaking, it's happening with incredible rapidity, even for a mass extinction. Yet not one moment during the day was taken up with this very current, very pertinent, very real catastrophe.

I realize that the topics covered by the day's speakers concerned past extinctions. I knew that going in because it was all listed in your literature (although the title "Mass Extinctions! Who's Next?" does imply something more current). Still, I was hoping it would come up during the 45 minute question-and-answer period that followed, and I did submit the question, "What about the *current* mass extinction? If it is tied to human population, can anything be done about it without a massive reduction of human population?" The question was never used; instead, the panel dealt with things of more universal concern, such as, "Are oxygen isotopes really reliable in determining ocean temperatures of the past?" It was almost as though it would be out of place in such a polite gathering to bring up such an unpleasant idea – particularly as it relates to human beings as the cause of the calamity. Yet, if an organization such as the Leakey Foundation is mute on the subject, just who is going to generate the awareness? I can see a newspaper headline, "Human Herd Causes Mass Extinction – Sleeps Through It All."

I should amend all this by saying that the matter of nuclear winter did come up, and that is current, pertinent and real. However, it's also something that hasn't occurred yet and is theoretically preventable and deserves a cry of alarm. Maybe that's the difference. The mass extinction that *is* going on has been going on for thousands of years and isn't preventable. It's already here and will only get worse and there's nothing the Leakey Foundation can do about it, so why bring it up and spoil the day's history lesson? I suspect that that is why it wasn't mentioned, why it was avoided, and I do understand that, I guess. It's just that it strikes me as being intellectually dishonest, and when that comes from the Leakey folks, I'm disappointed. I apologize if I'm mistaken.

Sincerely,
Bill Schohl
Los Angeles, California

continued from page 2

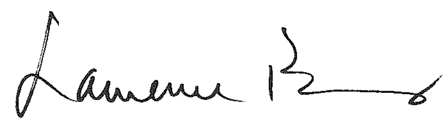
hemisphere and Africa caused by the advance in atomic weaponry. That some countries object to ships carrying atomic weapons to their shores, and to the French atomic tests in the South Pacific, is only a small part of it. These countries know they are an integral part of the world, tied to the tragedy that others may bring to them. These people ask me how I feel about responsible leadership among nations in the northern hemisphere. It seems incredible to them that so much money has been spent on atomic weapon proliferation. Can it still be argued that these inventories of sophisticated atomic weapons are a deterrent to warfare? I am hearing more and more from those who have become sensitive and perceptive to the increasing dangers of irrational or accidental or terrorist use of atomic weapons.

The question "Who's Next?" was not answered by the symposium. From the fossil record, we know much about species now extinct and we are learning more about those species for whose extinction we as humans may be responsible. From the question comes the obvious implication to me and to others that we may be next, because we may not control the consequences of our own cleverness.

The almost unbearable vastness of space cannot be ignored, nor can the immense journey of our own evolution into a species we call, at times with an ironic smile, *Homo sapiens sapiens*. Discoveries in space and in evolution have brought richness and excitement to our lives, as well as good science. We can be impressed by the tremendous growth of knowledge, with comfort and understanding. But somehow we do not seem yet to understand, nor can we feel comfortable with, the widespread growth of divisive stress among peoples in regard to atomic weapons. We know we can lose it all, that widespread use of nuclear weapons will cause greater damage than our human cultures can endure.

I believe that our species has the intelligence to deal with the problems of today. Recall Richard Leakey's and Roger Lewin's concept of "reciprocal altruism" in their chapter titled the Nature of Intelligence (*People of the Lake*).

It is expensive, painful and dangerous to continue attitudes of revenge, brinkmanship, bluff and double bluff. Responsible leadership should be able to cool emotions and bring solutions to conflicts between diverse people. Otherwise, the most likely and near term of all possible extinctions could be nuclear disaster.



A Folivore's Soliloquy

Tuber or not tuber, – that is the question:
Whether 'tis fitter in the stomach to suffer
The mistakes and errors of outrageous foraging,
Or to take hoe against a field of truffles,
And, by eating, end them? To forage, to sleep,
No more; and by a sleep to say we end
The heart-burn and the thousand natural upsets
That digestive tracts are heir to; 'tis a consummation
Devoutly to be wished. To forage, to sleep;
To sleep! perchance to be ill. Aye, there's the rub;
For in that sleep of digestion what secondary compound may come,
When we have shuffled off this mortal vigilance,
Must give us pause: There's the respect
That makes calamity of so long eating;
For who would bear the toxins and digestibility inhibitors of plants,
The Rutaceae's terpenoids, the Apocynaceae's phenolics,
The pangs of despised alkaloids, the excessive fiber's delay,
The insolence of competitors, and the thorns
That patient merit of the unwary take,
When he himself might his carnivorous diet make
With a bare herbivore body? Who would racemes bear,
To grunt and sweat under a weary bulk,
But that the dread of undependable forage,–
The unpredictable base, from whose bourn
No obligate carnivore may stray,– puzzles the genes,
And makes us rather bear those ills we have
Than fly to others that we know not of?
Thus evolution does make cowards of us all;
And thus the native hue of herbivory
Is sicklied over with the pale cast of dietary conservatism;
And adaptations of great pith and moment,
With this regard, their currents turn awry,
And lose the name of adaptive radiation. Soft you now!
The fair Ceres. Goddess, in thy orisons
Be all my appetites remembered.

Jim Moore, University of California, San Diego,
with apologies to the author of the original
and thanks to Jeanne Sept and Annie Vincent
(we knew their tubers) for the inspiration.

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