that only ~ 1 percent of the fallout ^{137}Cs has left the soil in solution (*13*), then ~ 0.3 curie of $^{239,240}Pu$ would have reached the Hudson in solution from the drainage basin soils.
19. A similar conclusion was reached in a recent study of low-level releases of radioactive wastes into Bombay harbor [B. Patel, C. D. Mulay, A. K. Ganguly, *Estuarine Coastal Mar. Sci.* **3**, 13 (1975)].
20. H. J. Simpson, R. Bopp, D. Thurber, in *Hudson River Ecology, Third Symposium on Hudson River Ecology* (Bear Mountain, N.Y., March 1973), paper 9; K. A. Abood, *Ann. N.Y. Acad. Sci.* **250**, 39 (1974).

21. We thank J. Kelly of Consolidated Edison of New York, Inc., for providing copies of operating reports for Indian Point, N. Chu of the Health and Safety Laboratory of the Energy Research and Development Administration for advice on plutonium chemistry and for supplying ^{236}Pu and ^{242}Pu spikes, and G. Mathieu and P. Breland for help in the coring operations. Financial support was provided by ERDA contract E (11-1) 2529. Contribution No. 2390 from Lamont-Doherty Geological Observatory of Columbia University.

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Histologic Structures Preserved for 21,300 Years

Abstract. *Histologic examination of rehydrated tissue samples from late Pleistocene (Alaskan) mammal mummies demonstrates that the preservative effect of freezing and drying extends to remains 15,000 to 25,000 years old. Some muscle and liver tissue retained identifiable histologic structures. Most tissues were completely disintegrated and partly replaced by masses of bacteria, an indication of considerable postmortem decay before the remains were entombed beneath the permafrost zone.*

The frozen, mummified bodies of a variety of late Pleistocene mammals have been discovered in Alaska in the course of gold mining operations. Geological studies in Alaska (*1*) have indicated that mummified remains are present only in the latest Pleistocene fauna, which radiocarbon dating suggests lived from 15,000 to nearly 25,000 years before the present. Frozen mammoths have been found in Siberia (*2*, *3*) and mummified seals in Antarctica (*4*). Autolyzed marrow tissue has been reported in older remains from northeastern Siberia (*5*) and Alaska (as is reported below), but the mummified remains from Siberia also seem to be restricted to the late Pleistocene fauna.

While there have been many examinations of human mummies (*6*), only a few frozen human mummies have been examined grossly or microscopically. These have included 2000-year-old Scythian bodies from Siberia (*7*), an Inca child dated to about 1300 years ago (*8*), and an Eskimo woman frozen for 1600 years (*9*). The preservation of histologic detail in the Eskimo body encouraged one of us (M.R.Z.) to examine the mummified remains of several late Pleistocene Alaskan mammals in the collection of the American Museum of Natural History. Previous microscopic study of such material has been limited to an examination of bone from an Alaskan Pleistocene mammoth, showing structure comparable to modern elephants (*10*). Our study is directed toward obtaining information on the preservation of microscopic structure by freezing and subsequent desiccation, and on the antiquity of any disease process that might be discovered.

The specimens examined were all collected in the Fairbanks district of Alaska under the auspices of Childs Frick (Frick Collection, Department of Vertebrate Paleontology, American Museum of Natural History). They include the face and right forefoot of an immature woolly mammoth (*Mammuthus primigenius*, F:AM 99927), nearly complete remains of a rabbit (*Lepus* sp., F:AM 99926), a lynx (*Lynx* sp., F:AM 99925), a lemming or vole (F:AM 99928), and marrow from a horse canon bone (*Equus* sp., F:AM 99929). Carbon-14 dating of the mammoth indicated an age of 21,300 ± 1,300 years (Lamont Geological Observatory L-601, 1960) (*3*); and the lynx, rabbit, and rodent probably fall within the range of 15,000 to 25,000 years on the basis of stratigraphic evidence. The horse marrow was taken from a specimen from the Gold Hill site now known to be pre-Wisconsinan (?Illinoian) in age (*1*).

The animals were dry and leatherlike, with skin and hair well preserved. Dissection of the mammoth head revealed preservation of the eyes as globoid structures filled with soft, white, cheesy material. The viscera of the rabbit were easily identifiable and appeared to be well preserved. The viscera of the lynx were totally autolyzed, and the marrow of the horse bone was reduced to a small amount of greasy yellow material.

Representative specimens of the various structures were selected for rehydration, which was based on the technique developed by Ruffer (*11*) for mummified human tissue. The specimens were immersed in a solution of distilled water, alcohol, and sodium carbonate until fully rehydrated to visual inspection, overnight immersion being sufficient. Of interest was the failure of the rehydration solution to turn dark brown, a change usually seen in the rehydration of human tissues. The lemming (or vole) was rehydrated in toto for a 1-week period, in an effort to facilitate identification.

After rehydration, the specimens were fixed in absolute alcohol and processed as would be fresh tissue. The sections were stained with hematoxylin and eosin, Masson trichrome, phosphotungstic acid hematoxylin (PTAH), and the Fontana stain for melanin, according to described techniques (*12*).

Histologic structure was found to be preserved in several of the specimens. The mammoth eye showed preservation of the extraorbital skeletal muscles, which retained their affinity for the Masson trichrome. The PTAH stain revealed preservation of the cross striations characteristic of skeletal muscle (Fig. 1). The melanin of the retina was not preserved, and no other structures could be identified.

The general architecture of the rabbit liver was preserved, the fibrous tissue of the portal areas being clearly visible (Fig. 2). The hepatocytes had completely disintegrated, being replaced by masses of bacteria. The wall of the rabbit bowel remained as strands of tissue, and the vegetable intestinal contents were well

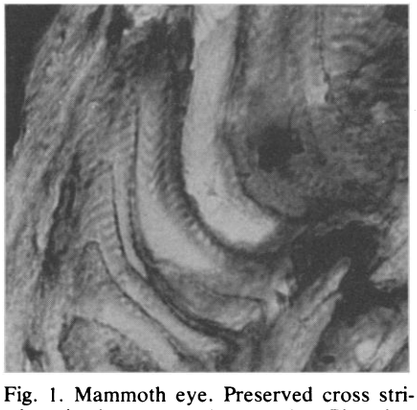

Fig. 1. Mammoth eye. Preserved cross striations in the extraocular muscles. Phosphotungstic acid hematoxylin stain (× 950).

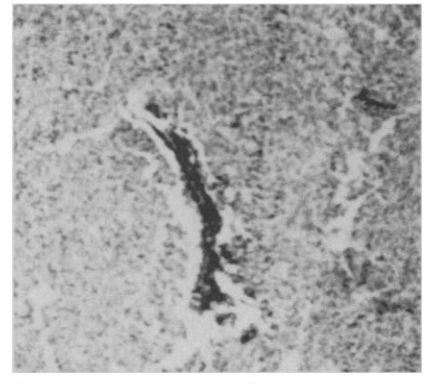

Fig. 2. Rabbit liver. The fibrous tissue of the portal area is preserved, although the hepatocytes have completely decomposed. Hematoxylin and eosin stain (× 95).

preserved. No ova or parasites were seen.

No traces of histologic structure were seen in the other tissues examined, including the heart and spleen of the rabbit, skin and muscle of the mammoth and lynx, and the horse marrow. No pathologic changes were recognized. The rehydration of the lemming (or vole) was only partially effective and did not aid in its identification.

Our study demonstrates the preservative effect of freezing and subsequent mummification to last much longer than previously suspected. Such results are very encouraging to the paleopathologist, interested in much more recent human remains, and to the paleontologist, for whom this technique may prove useful in studying evolutionary change at the microscopic level. It has been suggested that most human infections originated as zoonoses (*13*). The preservation of normal histologic structures in these ancient animal remains raises the possibility that the demonstration of disease organisms could yield evidence on this thesis.

On the other hand, the type and degree of destruction of tissue indicate that sufficient time elapsed between death of these animals and their entombment in the permafrost zone to allow considerable decay. This finding, plus the rarity of complete mummies of the larger species, demonstrates that after death these mammal remains were usually dismembered and partly decomposed before their entombment by the normal depositional processes of a periglacial environment. These conclusions directly counter the popular notion that the mummified remains indicate rapid freezing under conditions of catastrophic climatic change (*14*).

MICHAEL R. ZIMMERMAN
Departments of Pathology and *Anthropology, University of Pennsylvania, Philadelphia 19104*
RICHARD H. TEDFORD
Department of Vertebrate Paleontology, American Museum of Natural History, New York 10024

References

1. T. L. Péwé, *U.S. Geol. Surv. Prof. Pap. No. 835* (1975).
2. J. P. Tolmachoff, *Trans. Am. Philos. Soc.* **23**, 11 (1929).
3. W. F. Farrand, *Science* **133**, 729 (1961).
4. T. L. Péwé, N. L. Rivard, G. A. Llano, *ibid.* **130**, 716 (1959).
5. A. V. Sher, *Mammals and Stratigraphy of the Pleistocene of the Extreme Northeast of the U.S.S.R. and North America* (Nauka, Moscow, 1971).
6. T. A. Cockburn, R. Barraco, T. A. Reyman, W. H. Peck, *Science* **187**, 1155 (1975); M. R. Zimmerman, *Paleopathol. Newsl. No. 3* (1973), p. 11; A. T. Sandison, in *Science in Archaeology*, D. Brothwell and E. Higgs, Eds. (Praeger, New York, ed. 2, 1970), pp. 490–502.
7. S. I. Rudenko, *Frozen Tombs of Siberia* (Univ. of California Press, Berkeley, 1970); M. I. Artamonov, *Sci. Am.* **212**, 101 (May 1965).
8. T. Pizzi and H. Schenone, *Bol. Chile Parasitol.* **9**, 71 (1954).
9. M. R. Zimmerman and G. S. Smith, *Bull. N.Y. Acad. Med.* **51**, 828 (1975).
10. H. C. Ezra and S. F. Cook, *Science* **129**, 465 (1959).
11. M. A. Ruffer, *Studies in the Paleopathology of Egypt* (Univ. of Chicago Press, Chicago, 1921).
12. L. Luna, *Manual of Histologic Staining Methods of the Armed Forces Institute of Pathology* (McGraw-Hill, New York, 1968).
13. T. A. Cockburn, *Curr. Anthropol.* **12**, 45 (1971); D. Brothwell, in *Science in Archaeology*, D. Brothwell and E. Higgs, Eds. (Praeger, New York, ed. 2, 1970), pp. 310–314.
14. I. T. Sanderson, *Saturday Evening Post* (16 Jan. 1960), p. 39.

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Bat Mortality: Pesticide Poisoning and Migratory Stress

Abstract. *Organochlorine residues in the fat of young Mexican free-tailed bats,* Tadarida brasiliensis, *reached the brain and caused symptoms of poisoning after the fat mobilization that takes place during migratory flight was simulated. These chemical body burdens were obtained naturally under free-living conditions at the maternity roost. The data obtained support the hypothesis that pesticides have contributed to recent declines in populations of this bat.*

The Mexican free-tailed bat, *Tadarida brasiliensis*, is a migratory, colonial species. Each spring millions of individuals migrate north from wintering areas in Mexico to maternity roosts in the southwestern United States (*1*). In the late 1950's and early 1960's, about 150 million free-tailed bats were estimated to be living in 20 maternity colonies (*2*). It is estimated that, before the southward migration in October, such a bat population would consume more than 18,000 metric tons of insects (*3*). Recent observations, however, indicate that there have been drastic declines in populations of *T. brasiliensis*. For example, the size of the summer populations at Carlsbad Caverns, New Mexico, declined from an estimated 8.7 million in 1936 (*4*) to 200,000 in 1973 (*5*), and the population at Eagle Creek Cave, Arizona, dropped from about 25 million in 1964 (*1*) to 600,000 in 1970 (*6*). Pesticides and direct human disturbances have been suspected as possible causative agents in these declines (*7*). A recent study of pesticide residues in *T. brasiliensis*, however, showed no cause-and-effect relationship (*8*).

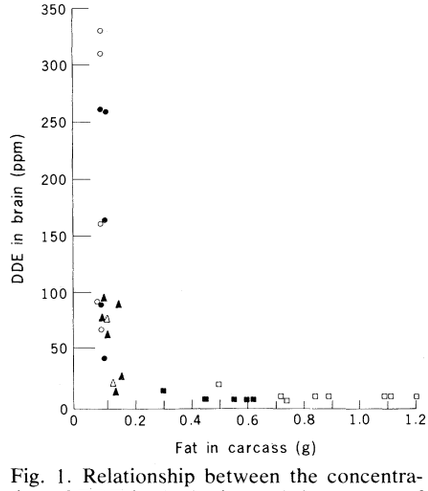

Fig. 1. Relationship between the concentration of DDE in the brains and the amount of fat in the carcasses of *Tadarida brasiliensis* from the reference (squares), unexercised (triangles), and exercised (circles) groups. Open symbols represent younger animals, and closed symbols represent older animals.

Free-tailed bats are born in early summer and reach adult size before leaving on their southward migration. Deposition of fat and a concomitant buildup of pesticide residues in nursing young continue until they begin to fly (*8*, *9*). Since organochlorine pesticides are fat-soluble and are readily stored in fat, individuals may not exhibit toxic effects unless fat reserves are used (*10*). However, rapid mobilization of pesticide-loaded fat can result in significant increases in the amounts of pesticide residues in the brain and can cause death (*11*, *12*). Because the maximum storage of fat and pesticides in *T. brasiliensis* occurs toward the end of nursing, we hypothesized, as others have (*8*), that the critical stage in the life cycle of these bats may be during the initial migratory flight, when the rapid mobilization of fat releases toxic residues that may reach the brain in lethal or detrimental amounts. By simulating in the laboratory the fat mobilization that occurs during migratory flight, we have demonstrated that significant increases in the organochlorine residues can occur in the brains of young, flying *T. brasiliensis*.

On 28 August 1974, 20 young *T. brasiliensis* were selected from bats netted during the evening exit flight from Carlsbad Caverns. Each bat was marked, the sex and body weight were recorded, and the relative age was determined from the amount of cartilage around the finger joints (*13*). The next morning these bats were transported to the University of New Mexico, Albuquerque, where they were housed in Wahmann slant cages (38 by 23 by 18 cm) and kept in an environmental chamber under a photoperiod of