the nucleus accumbens, they found that the levels jumped as much as twofold over those in the accumbens of control rats infused with an inactive cannabinoid. The magnitude of the surge was similar to what the researchers saw when they gave heroin to another set of rats.

Further work confirmed that cannabinoids, rather than other factors such as the stress of being handled by the experimenters, were responsible for the dopamine release. For example, the researchers observed no dopamine increase in animals who were given a receptor blocker before the THC.

Then Di Chiara and his colleagues found an additional parallel between THC and heroin. They showed that naloxone, a drug that blocks brain receptors for heroin and other opiates, prevents THC from raising dopamine levels, just as it does with heroin. This indicates that both marijuana and heroin boost dopamine by activating opiate receptors. Marijuana, however, presumably does so indirectly, by causing the release of an endogenous opiate: a heroinlike compound made in the brain. "Marijuana may provide one way of activating the endogenous opiate system," explains Di Chiara.

Di Chiara speculates that this overlap in the effects of THC and opiates on the reward pathway may provide a biological basis for the controversial "gateway hypothesis," in which smoking marijuana is thought to cause some people to abuse harder drugs. Marijuana, Di Chiara suggests, may prime the brain to seek substances like heroin that act in a similar way. Koob and Weiss add that the stress and anxiety brought on by marijuana withdrawal might also nudge a user toward harder drugs.

More work will be needed to confirm these ideas, as well as to find out exactly how marijuana influences the stress and reward systems. For instance, nobody knows how THC interacts with neurons in the amygdala to alter the release of CRF. Nor do scientists understand the molecular steps by which THC triggers the dopamine release in the nucleus accumbens.

But despite these uncertainties, both papers should help revise the popular perception of pot as a relatively—although not completely—safe substance to something substantially more sinister. "I would be satisfied if, following all this evidence, people would no longer consider THC a 'soft' drug," says Di Chiara. "I'm not saying it's as dangerous as heroin, but I'm hoping people will approach marijuana far more cautiously than they have before."

–Ingrid Wickelgren

PALEONTOLOGY

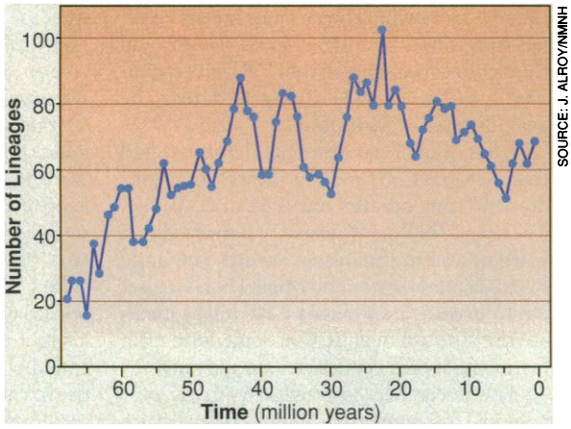
Climate-Evolution Link Weakens

We mammals have come a long way since our ancestors were a motley group of small creatures scurrying about in the shadows of the dinosaurs. We owe much of it to climate change, or so goes the conventional wisdom. Researchers have speculated that the innumerable warmings and coolings of climate pushed unfit mammals to extinction and spurred the evolution of new, better adapted species. But the best compilation of fossil evidence on mammal evolution to date now shows that climate had little effect on most of the evolutionary churnings of the past 80 million years.

"This is counterintuitive; I wanted to find a connection," says paleontologist John Alroy of the Smithsonian Institution's National Museum of Natural History. Only during a few brief periods did climate seem to drive evolution—although those periods are turning points in the history of mammals. Instead, the main determinant of the rate of evolution was the number of existing species, with new species appearing more slowly as the ark got more crowded. Alroy's results, presented at last month's meeting of the American Geophysical Union in Baltimore, are "pretty impressive," says paleontologist David Jablonski of the University of Chicago, "because it's been hard to get large-scale studies where you can look at" rates of evolution.

Alroy gained this overview by putting together a unique record of mammals. "It's the best piece of work in terms of methodology I've ever seen," says paleontologist Michael McKinney of the University of Tennessee, Knoxville. Alroy consulted 4015 lists indicating when and where 3181 North American mammal species lived during the past 80 million years. Then he adapted the record for statistical analysis by creating standard time intervals of 1 million years each and by dropping fossils from the most heavily sampled intervals, which would otherwise tend to look more diverse than sparsely sampled periods.

Alroy's final record of mammal evolution shows that mammal species were consistently scarce 80 million to 65 million years ago in the Cretaceous period, and the numbers dropped even lower during the mass extinction 65 million years ago at the time of the great impact. During the next 10 million years or so, diversity rose sharply, and then it settled into a more or less stable but higher plateau for the past 50 million years. Isotopic clues in the deep-sea sediments show numerous climate shifts over the same period, but Alroy found that most left no mark on mammal diversity.



Mammal ascent. Climate had little to do with the rise of mammal diversity after the impact 65 million years ago.

The reason mammals generally failed to respond to climate change, Alroy suspects, is that they were already adapted to an unsteady climate. Throughout the interval, cyclical variations in Earth's orbit have driven climate changes every 20,000, 40,000, and 100,000 years, he notes. The average species, surviving a couple of million years, would have to deal with repeated climate shifts.

Alroy's analysis may have put to rest the old saw about climate driving every twitch of evolution, but it could give new life to another old idea: that new species are more likely to form when ecological niches are unoccupied, as they were after the great impact catastrophe. His analysis shows that new mammal species originate at the highest rate when existing species are few.

Still, some researchers point out that climate has not been totally impotent. "It's fine that climate isn't important 95% of the time," says paleontologist Steven Stanley of The Johns Hopkins University, "but the things we have to focus on are the intervals when interesting things did happen." In fact, Alroy did find three short intervals—55, 34, and around 6 million years ago—when drastic global temperature shifts and heightened rates of diversity change did coincide. All three were times when mammal evolution took a major turn.

The diversity change Alroy identified 55 million years ago was modest, for example, but qualitatively it was a "critical interval," as Stanley has dubbed it. A host of modern mammals from primates to ungulates abruptly appeared in North America, in time with a sudden burst of warming that may have been driven by a sharp gush of greenhouse gas from the ocean's sediments (*Science*, 28 February, p. 1267). Climate may leave few marks on evolution, but they are lasting ones.

–Richard A. Kerr