nism by which a drug user experiences a hallucination. In some brain areas, the hallucinogen appears to inhibit nerve signals; in others, it unleashes a flood of them. The brain itself is an extraordinary tangle of neurons and chemical signals, and a reaction in one locality can set off multiple reactions throughout the brain mass—which is exactly why small amounts of most hallucinogens (often a few micrograms) can induce such powerful experiences. Also puzzling: The serotonin receptor sites seem to play a role in producing anxiety and migraine headaches.

A "critical" experiment remains to be done, says Jacobs, one that will help clarify how hallucinogens act on the brain. That experiment would involve giving human subjects drugs that block serotonin's actions at the special receptor sites, and then noting whether the subjects are still able to hallucinate when hallucinogens are administered.

But owing to federal restrictions on drug experiments, the author observes, such a test is a long way off.

America's Rhinos

"The Rise and Fall of the American Rhino" by Donald R. Prothero, in *Natural History* (Aug. 1987), Central Park West at 79th St., New York, N.Y. 10024.

Lumbering along on African or Asian plains, rhinoceroses are an impressive sight. With one grand horn (in some cases, two) planted firmly on their snouts, the thick-skinned, hairless mammals stand up to six feet tall and 14 feet long, and weigh as much as five tons.

They are loners, tending toward grasslands, savannas, or marshes. They have bad eyesight, a good sense of smell, and a mean temper. Most noticeably, they have the distinct look of a tropical animal.

But Prothero, a geologist at Occidental College, notes that until five million years ago, the grunting "odd-toed" beasts (which are surprisingly agile; they can run as fast as 30 miles per hour) were not exclusively a tropical oddity. They roamed North America in great numbers and in great generic variety, ranging from "sheep-sized runners to hippo-like grazers." In fact, the author observes, *Rhinoceros occidentalis* (Western rhinoceros) was "the commonest large herbivore on this continent for most of the last 50 million years."

"Nearly every continental ecosystem has a large mammalian herbivore that can eat the highest-growing, toughest vegetation and is relatively protected from predation by its size," says Prothero. Early rhino thrived in Eurasia and North America during the middle Eocene era, some 50 million years ago. The world was warmer then. There were no polar ice caps; the climate of North America was so temperate that alligators and semitropical plants flourished in Alaska. At that time, *hyrachyus*, a primitive, horse-like rhino dominated the landscape. It gave rise to three major generic lines: the amynodont (a stocky river dweller), the hyracodont (the long-limbed "running" rhino), and the primitive rhinocerotid (the ancestor of the modern rhino).

However, a worldwide cooling during the Oligocene era, some 30 million years ago, altered North America's vegetation. The amynodonts and hyracodonts could not adapt, and died off. (In Eurasia, the climate change encouraged evolution, briefly, of a "gigantic" rhino—the largest land mammal ever to live—which, weighing 25 tons, could "browse, giraffelike, in the tops of trees twenty-five feet high.")

For 25 million years, rhinos in North America struggled to survive. A "wave of immigrations" from Eurasia across the Bering Strait—which included the sheep-sized *menoceras*, the hippo-like *teleoceratines*, and the hornless *aceratherines*—helped keep the rhinos going. But by the end of the Miocene era, about five million years ago, the Ice Age finally did in North America's rhinos.

In Africa and Eurasia, five species of rhino did manage to survive. Yet today, says Prothero, their numbers are dwindling, as poachers push them inexorably toward extinction.

"Perhaps by the end of the century," Prothero concludes, "a few horns ground down as supposed medicines in the Orient or carved up into dagger handles for status-conscious Yemenite men will be all that is left of this amazing [rhino] family."

Analyzing Chaos

"The Coming of Chaos" by Robert Kanigel, in *Johns Hopkins Magazine* (June 1987), 34th and Charles Sts., Baltimore, Md. 21218.

The ups and downs of the stock market, the turbulence of a waterfall, the sudden changes of weather, the rise and fall of an animal population—all of these phenomena have defied prediction. Seeming to follow no regular pattern, they are deemed "chaotic."

But what is chaos? The dictionary defines it as "a state of things in which chance is supreme." Kanigel, author of *Apprentice to Genius: The Making of a Scientific Dynasty*, argues that there may not be such a thing as chance. As the latest discoveries in the new mathematical field of "chaos theory" demonstrate, "random" patterns are only those that do not fit standard linear models. However, they also have a unique and predictable logic of their own.

"Behind much of what passes in nature for formlessness, anarchy, or mere chance resides order—an order hard to discern," Kanigel says.

To reveal the elusive patterns in erratic systems, chaos theorists collect reams of data (such as light reflections off a waterfall's surface) and then feed it into a computer. The data is manipulated, reorganized, and "plugged" into a computer graphics program, where a pattern ("feathery, swirling") often will emerge. Some patterns arise with such regularity that they bear the name of the scientists who first noted their commonality: the Lorenz "mask," the Birkhoff "bagel," the Rössler "funnel."

Applications of the new mathematics are still in the early stages, Kanigel notes. Researchers are searching for hidden patterns in heartbeats and brain waves, in the tumbling of the planet Saturn's moons, and in rates of military arms buildup among nations. Boeing has used chaos models to streamline the tail section of its 767 jetliner. The U.S. Navy is employing chaos models to reduce drag on its warships.

The limits of chaos theory are still unknown. "Can such seemingly