PRIMATOLOGY

Habitat Seen Playing Larger Role in Shaping Behavior

INUYAMA, JAPAN—Most primatologists accept the idea that a female macaque's birth order is inversely related to her rank, that orangutans are solitary, and that male chimpanzees remain with their natal group for life. But data presented at a recent conference* here raise questions about all those bits of conventional wisdom. New studies offer evidence that nonhuman primates exhibit a greater range of behaviors than was previously thought, and that the environment—especially the accessibility of food—plays a major role in determining behaviors that were widely believed to be largely innate. "If [the findings] are true, it means rewriting the textbooks," says Jim Moore, a primatologist at the University of California, San Diego.

David Hill at the University of Sussex in England, also a primatologist, provided the challenge to conventional wisdom on macaque behavior. Hill has been observing a troop of Japanese macaques living under completely natural conditions on Yakushima, an island off the southern tip of Kyusha. Most of the previous studies of Japanese and rhesus macaques involve troops that are provisioned—fed by humans—but otherwise live in the wild. The difference in feeding appears to have a critical impact on behavior.

Previous researchers had noted that provisioning brings the animals in closer proximity to one another and results in more aggression. A mother may feel compelled to look out for her youngest, and thus most vulnerable, daughter in the competition for food. This special attention would translate into a higher ranking for the youngest siblings within the troop, which would extend into maturity in such areas as feeding and not being a target of aggression. Several researchers have speculated about how this so-called youngest ascendancy confers an evolutionary advantage.

In the Yakushima troop, however, dispersed foraging for leaves and fruit means that the mother's presence is not necessary to ensure that her youngest daughter gets her share. "We didn't see any evidence of youngest ascendancy," Hill says. He adds: "If the mechanism doesn't take place in nonprovisioned troops, then it's a bit early to be looking into the evolution of it."

Tetsuhiro Minami, a psychologist at Osaka University, is part of a team that has tracked, for 36 years, a provisioned troop of macaques in Katsuyama, in western Honshu. Youngest ascendancy is common there, he says, and "if it's not seen in Yakushima, that would be very interesting." But he cautions that one relatively short-term study is not enough to overturn decades of previous research.

Carel van Schaik, a professor of biological anthropology and anatomy at Duke University, has found that food availability plays a key role in behavioral differences among orangutans. The solitary image of orangutans is drawn primarily from studies in upland and mountainous areas of Borneo, whereas van Schaik has studied the animals living in a swamp forest on the west coast of Sumatra. His research team observed as many as 10 adults feeding together in the same tree and even saw coordinated group travel, both patterns of behavior rarely seen among their upland cousins. "Borneo orangutans are consistent with the stereotype of orangutans being solitary," van Schaik says. "The Sumatra [orangutans] are real partygoers."

DAVID HILL

Habit forming. Japanese macaques supplied with food behave differently from those that forage.

The reason for the difference, van Schaik speculates, is that upland orangutans have to forage over a wide area to gather a sufficient quantity of the leaves they feed on, and there would be no advantage in hunting in packs for widely dispersed food sources. But sustenance for the Sumatra primates—fruits and insects—is plentiful in the swamp. There's even a correlation between food availability and the size of the feeding party. "Gregariousness is a function of habitat productivity," van Schaik concludes.

Harvard University anthropologist Cheryl Knott says her work in Gunung Palung, in western Borneo, supports van Schaik's observations. The orangutans she has studied can be sociable, depending on seasonal variations in food availability and other factors, she says. Even so, she agrees on the need for further observation to gain "a broader understanding of how conditions affect primate social behavior."

Work by Yukimaru Sugiyama, a primatologist at Kyoto University's Primate Research Institute, has broadened the debate to chimpanzees. The classic studies of chimps have been in Gombe and Mahale in Tanzania, where males typically remain in the natal group throughout life and females often leave and join a neighboring community. But Sugiyama has observed a different pattern over 2 decades of observation in Bossou, Guinea: Both males and females tended to leave the Bossou group as adolescents, and males were actually more likely than females to leave. Of seven males born into the group during the study, for example, only one remained past adolescence. Although Sugiyama has no hard evidence that the wandering males survived, he believes it is unlikely that such a high number would have died or been killed by poachers.

Sugiyama also observed three different males joining the Bossou chimps and coexisting peacefully for varying periods of time before moving on. There is even evidence that wandering males can father offspring, perhaps by mating with females that wander from their group. Genetic tests indicate that the father of one now-adolescent member of the Bossou group came from outside it.

In Gombe and Mahale, Sugiyama says, male bonding within groups is believed necessary to defend territory, and trespassing males are not welcomed by other troops. In Bossou, however, the group is not habituated to the need to defend its territory because it has no close neighbors who might try to extend their own domain. Another incentive for mobility is the fact that the Bossou forest, although a rich source of food, is small and may be near its carrying capacity.

Anne Pusey, director of the Jane Goodall Institute's Center for Primate Studies at the University of Minnesota, St. Paul, says that the Bossou chimps live in an extremely disturbed area and that such conditions may explain their unusual behavior. "In Gombe, we don't have a single instance in 37 years of an adult male joining the community," she says, adding that the norm is for males to remain with their natal group.

Others have also raised questions about

* "Recent Trends in Primate Socioecology," 5–8 January, Inuyama, Aichi Prefecture, Japan.

the significance of the new findings. Michael Huffman, a primatologist at Kyoto's primate institute, agrees that many social behaviors are likely to be influenced by environmental factors. But others—such as mating preferences—are likely to be consistent throughout a species, regardless of habitat. "If you look long enough, Japanese macaques are still Japanese macaques," he says. And Maria van Noordwijk, a primatologist at Duke University, questions drawing conclusions from small data samples. Hill's study, she notes, covers only one troop.

The bottom line for all these researchers is the need for additional studies. And that takes long-term funding, which is always in short supply. The need to generate results in 2 or 3 years, says San Diego's Moore, forces researchers to return to the same small bands. "People have [difficulty] getting secure funding for studies of wild, undisturbed, initially unhabituated animals, where the most interesting results can easily take 5 to 10 years to start coming in," he says. If that situation doesn't change, he predicts, questions about which traits are inherited and which are flexible could remain unanswered.

–Dennis Normile

COSMOLOGY

Inflation Confronts an Open Universe

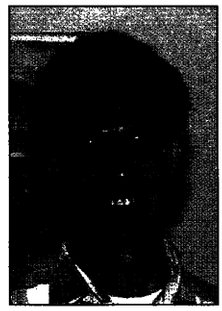
It is not often that debates over the finer points of cosmology are played out in the pages of daily newspapers, but last week several British papers gave their readers a glimpse of a passionate dispute between some of the mightiest theorists in the known universe. On one side are Cambridge University cosmologists Stephen Hawking and Neil Turok, and on the other is Stanford University's Andrei Linde. Their disagreement—spelled out in reports awaiting publication in physics journals and currently circulating on the Internet—revolves around how to reconcile events in the earliest moments of the big bang with the other end of time: the eventual fate of the universe.

Many cosmologists had long assumed that the universe contains just enough matter that gravity would eventually halt its expansion to give what is known as a "flat" universe. But recent astronomical evidence suggests that there is not enough matter and that the universe will expand forever, yielding a so-called "open" universe. Hawking and Turok have come up with a mathematical explanation for how a subatomic-sized universe can spring into existence, then transmute into an open-ended, ever-expanding one. But Linde is not convinced. A few days after Hawking and Turok released their paper as a preprint, Linde produced a long paper disputing their conclusions. This was swiftly followed by a rebuttal from the Cambridge researchers.

Both sides invoke inflation theory, which proposes a period of stupendous expansion of the universe, starting when the universe was about 10^{-34} seconds old and lasting perhaps 10^{-32} seconds. Because inflation deftly tackles several prickly problems in cosmology, such as the remarkably even appearance of the universe in every direction, it has become received dogma among most cosmologists. Inflationary models traditionally favor a flat universe. But recent results, ranging from measurements of the recession of distant supernovae to the small changes seen in galactic clusters over recent cosmic history (*Science*, 31 October 1997, p. 799), seem to point to an open universe. As a result, some cosmologists, including Turok and Hawking, have been exploring ways of producing an open, inflating universe.

"What we've found is a new set of solutions that describe the beginning of an open universe," says Turok. The work—accepted for publication in *Physics Letters B* in just 3 days—combines a quantum equation for the universe proposed by Hawking and collaborator Jim Hartle in 1983 with a method of spawning an open universe proposed in 1995 in an influential paper by Turok, Martin Bucher of Princeton University, and Alfred Goldhaber at the State University of New York, Stony Brook.

JAMES D. WILSON/GAMMA LIAISON



IAN GRANT/CAMBRIDGE UNIVERSITY

CERN

Open debate. Inflation protagonists Stephen Hawking *(top left)*, Neil Turok *(top right)*, and Andrei Linde.

But their solution has a glitch: The approach produces many possible universes, most of which are devoid of matter. To avoid this outcome, Turok and Hawking resort to a controversial fix known as the anthropic principle: If a universe is empty, there will be no one to observe it, so it is not worth considering. Thus, Hawking and Turok discard observerless universes and home in on those with the most matter. But they still end up with a universe that is very sparsely filled: Its mass density is a mere 100th of the critical value for a flat universe.

Linde is not impressed. "This prediction tells us that we must practically live in an empty universe, which disagrees with observations," he says. But Turok counters that the new result "applies only to the simplest versions of inflation." He believes that a more complete theory will predict a mass density closer to 30% of the critical value—a figure currently favored by astronomers. Nonetheless, Linde describes their results as "disastrous."

Linde disputes the pair's use of the Hartle-Hawking "wave function" equation for the universe. "I believe this wave function does not describe the creation of the universe," he says. Instead, Linde offers his own, alternative wave function, based on a quantum tunneling approach. In a paper submitted to *Physical Review*, Linde outlines how, when this equation is combined with the Hawking-Turok model, it predicts a flat universe. He also claims that his own recipe is capable of creating a whole range of open universes from inflation, yet it gives nonsense results if fed the Hartle-Hawking wave function.

Turok contends that Linde's reply is "mathematically inconsistent," adding, "I think what his paper has done is basically thrown a large amount of confusion into the subject." Last week, Turok and Hawking released a rebuttal of Linde's criticism. However, Alan Guth of the Massachusetts Institute of Technology, who invented inflation theory back in 1981, thinks that Hawking and Turok may be fighting the wrong battle, attempting to recast inflation theory in a way that makes it work for an open universe. "I still strongly suspect that the universe will turn out to be flat," says Guth, "because the models of inflation that give open universes seem to me to be somewhat more contrived."

Turok believes forthcoming experimental data will help resolve matters. "The cleanest way to test these theories is to look at the microwave background radiation left over from the big bang," says Turok. "If the universe is open, and if the scenario we are discussing is correct, there will be a distinct pattern of fluctuations on the microwave sky." NASA's Microwave Anisotropy Probe, due to fly in 2 years' time, is designed to look for exactly these kinds of patterns. So too is the European Space Agency's Planck mission, due to fly in 2006. So keep watching those morning papers.

–Andrew Watson

Andrew Watson is a writer in Norwich, U.K.