van Schaik. Most orangs won't touch the fruit after it ripens, however, because the seeds are then surrounded by stinging hairs. But one population, in Sumatra, uses sticks to scrape out the hairs and get at the seeds. "The whole population knows the trick," van Schaik says. "It's very similar to what we see in some chimp populations." And it's the only case in which orangs—skilled tool users in captivity—have been spotted using tools in the wild.

Orangs that avoid ripe neesia have the same sticks available for tools, so lack of materials can't explain why their behavior differs, van Schaik says. The key difference, he and his colleagues found, is that whereas most orangs are solitary, the Sumatran tool-using animals travel and feed close together, perhaps because there is plenty of food to go around. In most environments, food is thinly distributed and the animals "can't afford" to forage together, says van Schaik. The extra interaction in Sumatra allows an invention by one animal to spread when its compatriots observe it, he adds.

The pattern also holds for chimpanzees, as van Schaik and his colleagues report in this month's issue of the *Journal of Human Evolution*. In a survey of the behaviors reported at the five longest running chimp field studies, the researchers found that those with higher "social tolerance" (measured by the amount of meat sharing, female-female grooming, and similar indicators) have more varied tool use. The theory could help to explain why captive primates are better at using tools than wild ones, as animals in captivity have more chances to observe one another and have plenty of food, van Schaik says.

The correlation might help explain the rise of human tool use as well. The earliest tool-using hominids "didn't have a much bigger brain yet, so we shouldn't look for major cognitive advances," van Schaik says. "I hypothesize that there was a social change that made them tolerate each other," which led to increased opportunities to learn and build on each other's inventions.

The fossil record might support such a theory, says anthropologist John Fleagle of the State University of New York, Stony Brook. Ancient humans have small canine teeth and lots of tools compared to other apes, he notes, and "when you look at the fossil record, you see reduction of canines early and tools later." He thinks smaller teeth might be a sign of increased tolerance, as canines are often used in fighting among group members. "And once you have tolerance, you have bigger tool kits."

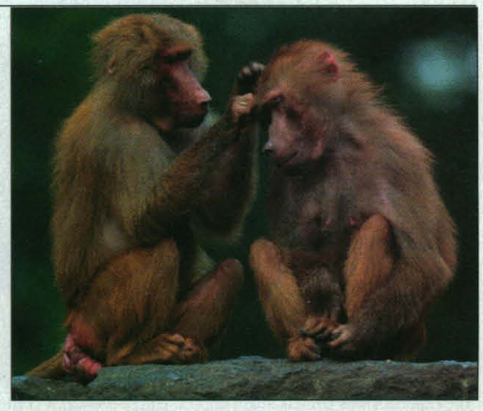
But the researchers attempting to learn the roots of culture by studying wild primates worry that they are running out of time. Habitat loss and increased hunting are pushing many great ape populations to the brink of extinction. Illegal loggers are threatening the Sumatran orangutans that van Schaik studies. And on a recent market day at the village of Taï, just outside the park where Boesch works, three chimpanzee heads were stashed in the game warden's office, confiscated from poachers. If Boesch and his colleagues are correct, says Whiten, such sights mean "we're not just losing chimpanzees; we're losing lots of different chimpanzee cultures." That, he says, would be a major loss for humans. "If we want to understand how humans came to have the minds we have and the cultures we have, then we're only going to learn about that by looking for similar characteristics in our close relatives"—close relatives who are fast disappearing.

–GRETCHEN VOGEL

PRIMATE ABILITIES
▶ CONSCIOUSNESS

Are Our Primate Cousins 'Conscious'?

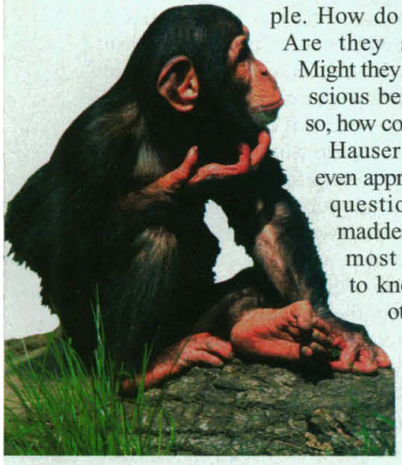
With animals brandishing both tools and symbols, consciousness seems the last stronghold of human uniqueness. But might primates also have some elements of self-awareness? A new generation of researchers seeks to find out



Know thyself? Female baboons behave as if fully aware of their own social status as well as the status and kinship of others in their group.

CREDITS: (LEFT TO RIGHT) J. & P. WEGNER/ANIMALS ANIMALS

When Marc Hauser sat down to write his soon-to-be-published book, *Wild Minds*, he knew he was in for a wild ride. The Harvard University cognitive neuroscientist was about to ask questions that philosophers have struggled with for millennia—and he was asking them about animals, not people. How do they think? Are they self-aware? Might they even be conscious beings—and if so, how could we tell?



Hauser admits that even approaching such questions can be maddening. It's almost impossible to know what another person is experiencing unless they tell you, so how can scientists ever know what nonverbal animals are thinking? And there's no consensus on exactly what consciousness is, much less how to test for it. All the same, Hauser and increasing numbers of neuroscientists, psychologists, and ethologists hope to yank such questions out of the realm of philosophy and into empirical science. They seek to create a scientific foundation for understanding just what it is that makes the human mind so different from those of our hairier cousins.

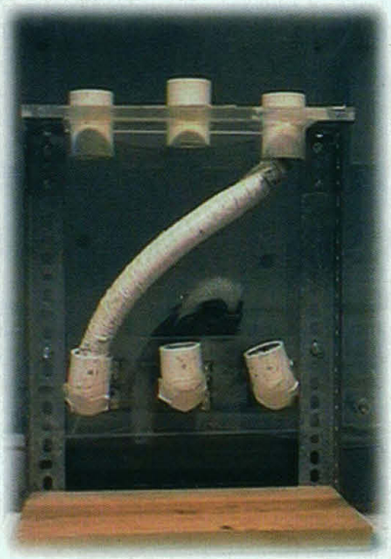
Researchers are designing clever new ways to test primates for some of the concrete abilities long considered to be prerequisites for consciousness, such as overcoming instinctive behavior; being aware of oneself and of others (and knowing the difference); and, most sophisticated, understanding that others also have mental states and thoughts. By borrowing from studies of infants and comparing results among primates and children of various ages, these scientists are beginning to understand where on the continuum of intelligent beings chimps and monkeys fall. Less advanced primates are turning out to be capable of sophisticated activities such as tool use (see sidebar on p. 2075), while other primates appear to be closer to humans than has often been assumed.

For example, some monkeys can overcome instinctive behavior to solve a problem more easily than can 2-year-old children. Other experiments seem to show that chimpanzees can attribute thoughts and intentions to each other. Species "have conscious behavior attuned to their ecological niches and show different levels of conscious behavior depending on the situation," says ethologist Irene Pepperberg of the Uni-

versity of Arizona, Tucson.

But other scientists find these experiments unconvincing, no matter how cleverly they are designed. Given that animals can't talk, says Celia Heyes, a psychologist at University College London, "I'm just mystified how anybody thinks you can find out about consciousness in other creatures."

Even some animal-cognition researchers caution that interpreting states of mind from an animal's behavior is always problematic. They heed a warning by the 19th century psychologist Lloyd Morgan, who argued that one should always look for a simple, mechanistic explanation for even the most complex animal behaviors, because complex behaviors don't always require complex thought. Children use correct grammar, for example, long before they understand what nouns and verbs are. "When we engage in certain behaviors, we're convinced that it's thought that prompted the behavior," says Daniel Povinelli, a cognitive scientist at the University of Southwestern Louisiana in Lafayette. "But the exact same behaviors can be generated by other means." Such skeptics argue that although animals may be smart, in the sense of having excellent information-processing capabilities, they lack the subjective experiences that are the essence of human consciousness.



Child's play. Giving tamarins and children the same tests helps researchers understand the cognitive limits of both species.

Thus, opinions on how wide a chasm separates us from other primates diverge wildly. Yet researchers on all sides agree that finding just what abilities lie in the gap will help us learn more about both primates and ourselves—and perhaps our ancient hominid ancestors to boot. What we learn about chimps, our closest living relatives, "will help us reconstruct the evolution of the human mind," predicts Andrew Whiten, an evolutionary psychologist at the University of St. Andrews in Fife, Scotland.

From tools to empathy

Back in the 1950s, anthropologists drew the line between human and ape at the use of tools; thus any ancient hominid associated with stone tools was automatically assigned to our genus, *Homo*. But then in the 1960s primatologists found that chimpanzees can use tools, and now researchers know that many other primates can too. Next it was language that was held to be the truly unique human skill—but then in the 1970s, primates were found to have symbolic representations for objects, although they do not fully master syntax. Now the distinction chiefly rests on what is called consciousness, and in psychological circles the term has come to include an ever-expanding range of cognitive abilities, says evolutionary psychologist Richard Byrne of the University of St. Andrews.

On the simplest level, consciousness is being aware of oneself and others; some researchers also say that it is correlated with creativity, language, and some form of empathy—putting oneself into another's shoes. Clearly, other primates lack this full package of abilities. But in the past 5 years, researchers have devised new tests that dissect consciousness more finely. For example, Hauser has decided to tackle what many think is an important step on the road to consciousness: the higher order cognitive function that enables individuals to override instinct and solve a problem in a new way. People do this all the time, for example, every time they see a cookie in a bakery window and walk away from the window and up to the counter to buy one, rather than succumbing to the impulse to reach through the glass and grab it.

Traditionally, behaviorists had assumed that animals behaved instinctively and could not restrain a particular response to a problem even when it failed repeatedly. The tendency to do what's routine is called perseveration, and neurobiological studies have located the ability to overcome it in the prefrontal cortex, a part of the brain that is much enlarged in humans (*Science*, 15 August 1997, pp. 900, 953). Human adults are able to judge immediately when they need to do something differently. But new results blur the animal-human distinction by showing that human infants can't always vary their instinctive response, whereas other primates sometimes can.

For example, in experiments Hauser described in January in Denver at the annual meeting of the Society for Integrative and Comparative Biology, he and Bruce Hood of the University of Bristol in the U.K. and their colleagues tested whether primates and children could overcome their instinctive anticipation of where a ball or a food pellet would drop. They used a frame with three chimneys at the top and three boxes lined up under the chimneys. Instead of falling straight to the ground, however, the ball was sometimes shunted over to a different box through either an opaque or transparent shunt; the subject's task was to predict where a ball dropped down a chimney would land.

Children over age 3 could always predict the ball's course based on how the shunt was positioned. But children under 3 and monkeys had similar difficulties with this task. Young children predicted the right landing spot only if the ball dropped straight down or they could see the ball moving through a transparent shunt. Cottontop tamarins—primitive primates weighing only 500 grams—reacted much the same way: They were able to find a food pellet if it fell straight down but not if it was shunted to another landing spot in an opaque shunt. But when the researchers put the apparatus on its side so that the objects were moving horizontally—thereby avoiding any gravity-related instincts—the monkeys did much better than the younger children in anticipating where the ball or pellet would emerge, says Hauser. No one is suggesting that cottontop tamarins are conscious, but the work shows a continuum of abilities in primates and humans, rather than a single cutoff.

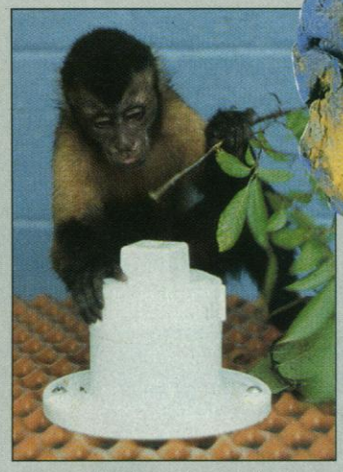
And because 2-year-olds make many of the same mistakes as the monkeys and on some tasks do worse, even though they have language, the experiments also suggest that overcoming perseveration has little to do with language. For example, language can't help children predict where the ball will fall. "We think of ourselves as thinking in language, and thus it's easy to conclude

CREDITS: LAURIE SANTOS AND MARC HAUSER/PRIMATE COGNITIVE NEUROSCIENCE LAB/HARVARD

In Labs, Organ Grinders Take Up Tools

Consciousness isn't the only ability once thought to be uniquely human that may be slipping down the evolutionary scale (see main text). Decades ago, it was tool use that was said to mark the divide between humans and other primates—but then chimpanzees and other apes were spotted using tools. Now even the capuchin monkey, the organ grinder's accompanist, turns out to be adept at turning sticks into digging implements and leaves into containers.

These 4-kilogram, nimble-fingered primates split off from the more intelligent apes a full 30 million years ago, and human observers hadn't seen many feats of intellectual prowess when watching them in their native rainforests of South America. But laboratory experiments tell a different story, says Greg Westergaard, who now directs the research division of a private primate facility, LABS of Virginia Inc. in Yemassee, South Carolina, and is an adjunct researcher with the National Institutes of Health.



Arts and crafts. Capuchins make probes to reach honey enclosed in containers *(left)* and work hard shaping and painting clay like this 5.5-cm "sculpture" *(above)*.

To prove an animal is smart, says Westergaard, the key is to watch it learn in new situations—and not to teach it. In the past, good training strongly reinforced with food rewards was often confused with intelligent behavior. So as a staff fellow at the Laboratory of Comparative Ethology at the National Institute of Child Health and Human Development, Westergaard and NICHD psychologist Stephen Suomi rarely included training with food rewards as part of the plan. Rather, they exposed the monkeys to everything from cups to clay and designed experiments based on spontaneous behaviors observed as the groups play.

In one experiment, for example, they buried peanuts, provided branches of various sizes, and observed how the monkeys retrieved these subterranean treats. Many tried to dig the peanuts out with their hands; some tried poking at the ground with various branches; and a few even broke the branches and removed the bark and leaves, making more effective digging tools. That shows sophisticated tool manufacture and creative problem-solving, says Westergaard.

Westergaard attributes his discoveries about the capuchins to working in the lab, where he can keep the monkeys happy and alert and observe them intensively, noting unexpectedly sophisticated behavior. Capuchins revel in shaping and painting clay, for example, and do it for hours with no food reward, he says. And in what appears to be rudimentary symbol use, they can learn to associate a particular color chip with a particular tool and can "ask" for a certain tool by giving an experimenter the right color.

Now the lab-based discoveries about tool use have been verified in the wild. Last year, Kimberly Phillips of Hiram College in Hiram, Ohio, reported in the *American Journal of Primatology* that capuchins in Trinidad use leaves as sponges and rudimentary water containers; there's even one report of capuchin monkeys clubbing a snake with a stick. Among primates, it seems, tool use is a popular trick. **–E.P.**

CREDITS: G. C. WESTERGAARD/NATIONAL INSTITUTES OF HEALTH/LABS OF VIRGINIA INC.

that language is doing all the work," Hauser explains, but it's not. William Kimler, a historian of science at North Carolina State University in Raleigh, agrees: "It's not about language; it's about planning."

Beyond mirrors

Almost everyone agrees that self-awareness, or being cognizant of one's body and thoughts, is another crucial element of consciousness, and many researchers think that chimps possess it. Alone among primates, chimps can recognize themselves in a mirror. But Robert Seyfarth and Dorothy Cheney at the University of Pennsylvania, Philadelphia, who have studied vervet monkeys and baboons in the field in Africa for 20 years, wondered if these primates might have self-awareness, too. Seyfarth and Cheney contend that the mirror test isn't relevant for species that in the wild would never have the opportunity to look in one. Because primates live together in tight hierarchies, they argued that a better test would involve "social self-awareness"—whether individuals understand themselves and their relations to other group members. "If you divide self-awareness into its components, then here's an aspect where we may be able to make progress," Seyfarth says.

For example, in one recent study, he and Cheney studied how pairs of female baboons reacted to recorded sounds of other adults in a fight. If the adults were not their own kin, the females didn't react. If the cries came from one female's relatives, the other female would look at her, and if both the females were related to the rabble-rousers, then the two females looked at each other and, eventually, the dominant one came and sat down in the place of the subordinate one, reasserting her place in the hierarchy.

"This suggests they know the individuals [and their calls] and also the family relationships of each individual," Seyfarth reported at this year's integrative biology meeting. The work "nails down the fact that these animals show an awareness of their own position in society and their position with respect to others," says Carel van Schaik, a biological anthropologist at Duke University in Durham, North Carolina. That sophisticated knowledge of their social selves, says Seyfarth, "raises the possibility that they have a sophisticated sense of self."

The mind problem

If self-awareness is part of consciousness, perhaps the next significant step is the ability to attribute mental states to others. In 1978, a hand-raised chimp named Sarah seemed to be able to understand what a human tester in a video should do to solve problems such as reaching food on a high shelf. To some, this suggested that chimps had a "theory of mind"—that they understood that other individuals had thoughts and mental states, too.

Critics argued that the experiment was very contrived, however, and it took researchers years to come up with better tests. Now several groups are doing such experiments on primates. And the primate work fired the imaginations of child development researchers, so that there are now hundreds of papers on children's development of theory of mind. That work shows that children become sensitive to what others are thinking at an early age, but are unable to attribute false beliefs to others until around age 5.

For chimps, however, the results are conflicting. For example, as part of a major program tracking cognitive development of both chimps and children for the past 8 years, Southwestern Louisiana's Povinelli

had his subjects gesture to one of two people—one with a blindfold and another with a gag over the mouth—in order to ask for a treat. Children of age 2 understood that the blindfolded person could not see their gesture and asked the gagged person, but chimps were just as likely to gesture to either person. "They are not reasoning about seeing," says Povinelli. He concludes: "Humans have a whole system that we call theory of mind that chimps don't have."

Work by Josef Call, a psychologist at the University of Liverpool in the United Kingdom, agrees in part with this conclusion. In the March-April issue of *Child Development*, Call's team reports that they could find no evidence that five chimps and two orangutans could figure out where a tester should find a hidden piece of food whose position has been switched without the tester's knowledge, although the animals themselves observed the switch. They were not sophisticated enough to realize that the tester had the wrong knowledge of the food's location, presumably because they couldn't fathom that the tester had knowledge different from their own.

Still, this was a test of one of the most sophisticated aspects of the theory of mind, says Call. "The theory of mind is not just one skill; it's a series of skills," he says, and he thinks that primates might still understand something of others' thoughts.

Indeed, some positive results are now appearing. For example, Harvard graduate student Brian Hare, who works with Call in the lab of developmental psychologist Michael Tomasello, now at the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, sought to design a scenario more relevant to chimps' lives than previous tests were. Because chimps forage in groups and have an elaborate set of rules about who gets to eat food first, Hare devised a test that looked at whether one chimp could tell what another chimp, rather than a human tester, was seeing—and presumably, thinking. Their setup involved three opaque cages in a row, with a chimp in the first and third cages and two pieces of food in the middle cage.

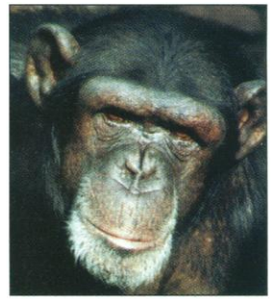
The doors from the outer cages to the middle one were first opened just enough that each chimp could peek at the food and see that the other chimp was eyeing it too. When the door was opened fully, only the dominant chimp of the pair retrieved the food, as would have been the case in the wild.

The researchers then placed a barrier in such a way that the dominant chimp could see only one piece of food, but the subordinate could see both and could also see that only one piece of food was in view of the dominant chimp. This time, the subordinate took the piece of food that the dominant couldn't see, suggesting that it knew the dominant was unaware of this food's existence. And when the dominant chimp was replaced with a chimp even lower on the hierarchy, the newly dominant chimp first went after the food both chimps could see—grabbing the potentially more contested item first—and then retrieved the second piece. Thus the chimp's response varied depending on its fellow's identity and what it could see, suggesting an understanding of another's visual perspective.

Similar hints that chimps know what is going on in each other's heads come from Tetsuro Matsuzawa and his team at Kyoto University in Japan. They also looked at food retrieval, this time by pairs of chimps—a "witness" chimp who had seen where food was hidden and a "bystander" who hadn't. In a variety of experimental protocols, the "bystander" tended to follow the "witness" around and so appeared to understand the witness's knowledge, says Matsuzawa. In addition, the witness sometimes misled the bystander by leading it to an empty box, the team reported in June 1998 at the Napoli Social Learning Conference in Italy.

In both sets of experiments, chimps are behaving as if they have a rudimentary awareness of their fellows' desire to find food—the first stirrings of mind-reading, says Matsuzawa. A few other experiments show similar abilities. One provocative study by psychologists Charles Menzel, Sue Savage Rumbaugh, and Duane Rumbaugh of Georgia State University in Atlanta and their colleagues involved a chimp named Panzee, who learned to communicate with a special computer keyboard outfitted with symbols. When seeking objects hidden outside her habitat, Panzee apparently understood that certain human keepers did not know what was hidden and where, and she told them both what the object was and what they needed to know to help her find it, according to a paper in press in the *Journal of Comparative Psychology*.

These data are too new to be definitive and are bound to elicit tough scrutiny by both supporters and skeptics. Researchers like Tomasello, for example, don't think that chimps have a full theory of mind. "Seeing and perceiving is not the same thing as knowing and believing," he says. Tomasello adds that the conflicting evidence about chimp consciousness may reflect the difference between animals raised in the wild and in captivity. He suggests that chimps raised by humans, such as Panzee, may be more likely to develop a sense of self and possibly an awareness of others. Human babies, he speculates, learn to recognize how others react to them and become self-aware because of the attention they get from adults. Thus, a human raised in isolation might not have the same "consciousness" as the rest of us, whereas chimps raised by people do uncharacteristically well in theory-of-mind experiments.



Researchers admit that they expect to puzzle over the theory of mind for a while. But as they design cleverer and cleverer experiments, they are optimistic about beginning to chart the still-unknown territory that divides the human and animal minds. "These are exciting times," says Harvard's Hauser. "I predict we will make immense progress." **–ELIZABETH PENNISI**

Primate literacy? Adept at using symbols, this chimp seems more humanlike than most of her species.

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