

# THE MIND

BY MARC HAUSER

## THE ORIGIN

**The first step in figuring out how the human mind arose is determining what distinguishes our mental processes from those of other creatures**

### KEY CONCEPTS

- Charles Darwin argued that a continuity of mind exists between humans and other animals, a view that subsequent scholars have supported.
- But mounting evidence indicates that, in fact, a large mental gap separates us from our fellow creatures. Recently the author identified four unique aspects of human cognition.
- The origin and evolution of these distinctive mental traits remain largely mysterious, but clues are emerging slowly.

—The Editors

**N**ot too long ago three aliens descended to Earth to evaluate the status of intelligent life. One specialized in engineering, one in chemistry and one in computation. Turning to his colleagues, the engineer reported (translation follows): “All of the creatures here are solid, some segmented, with capacities to move on the ground, through the water or air. All extremely slow. Unimpressive.” The chemist then commented: “All quite similar, derived from different sequences of four chemical ingredients.” Next the computational expert opined: “Limited computing abilities. But one, the hairless biped, is unlike the others. It exchanges information in a manner that is primitive and inefficient but remarkably different from the others. It creates many odd objects, including ones that are consumable, others that produce symbols, and yet others that destroy members of its tribe.”

“But how can this be?” the engineer mused. “Given the similarity in form and chemistry, how can their computing capacity differ?” “I am not certain,” confessed the computational alien. “But they appear to have a system for creating new expressions that is infinitely more powerful than those of all the other living kinds. I propose that we place the hairless biped in a different group from the other animals, with a separate origin, and from a different galaxy.” The other two aliens nodded, and then all three zipped home to present their report.

Perhaps our alien reporters should not be faulted for classifying humans separately from bees, birds, beavers, baboons and bonobos. After all, our species alone creates soufflés, computers, guns, make-up, plays, operas, sculptures, equations, laws and religions. Not only have bees and baboons never made a soufflé, they have never even contemplated the possibility. They simply lack the kind of brain that has both technological savoir faire and gastronomical creativity.

Charles Darwin argued in his 1871 book *The Descent of Man*

HOLLY LINDEM (photo/illustration); GENE BURKHARDT (styling)



that the difference between human and nonhuman minds is “one of degree and not of kind.” Scholars have long upheld that view, pointing in recent years to genetic evidence showing that we share some 98 percent of our genes with chimpanzees. But if our shared genetic heritage can explain the evolutionary origin of the human mind, then why isn’t a chimpanzee writing this essay, or singing backup for the Rolling Stones or making a soufflé? Indeed, mounting evidence indicates that, in contrast to Darwin’s theory of a continuity of mind between humans and other species, a profound gap separates our intellect from the animal kind. This is not to say that our mental faculties sprang fully formed out of nowhere. Researchers have found some of the building blocks of human cognition in other species. But these building blocks make up only the cement footprint of the skyscraper that is the human mind. The evolutionary origins of our cognitive abilities thus remain rather hazy. Clarity is emerging from novel insights and experimental technologies, however.

## Singularly Smart

If we scientists are ever to unravel how the human mind came to be, we must first pinpoint exactly what sets it apart from the minds of other creatures. Although humans share the vast majority of their genes with chimps, studies suggest that small genetic shifts that occurred in the human lineage since it split from the chimp line produced massive differences in computational power. This rearranging, deleting and copying of universal genetic elements created a brain with four special properties. Together these distinctive characteristics, which I have recently identified based on studies conducted in my lab and elsewhere, constitute what I term our humaniqueness.

The first such trait is generative computation, the ability to create a virtually limitless variety of “expressions,” be they arrangements of words, sequences of notes, combinations of actions, or strings of mathematical symbols. Generative computation encompasses two types of operation, recursive and combinatorial. Recursion is the repeated use of a rule to create new expressions. Think of the fact that a short phrase can be embedded within another phrase, repeatedly, to create longer, richer descriptions of our thoughts—for example, the simple but poetic expression from Gertrude Stein: “A rose is a rose is a rose.” The combinatorial operation, meanwhile, is the mixing of discrete elements to engender new ideas, which can be expressed as novel words

## KEY INGREDIENTS OF THE HUMAN MIND

**The four traits below distinguish the human mind from those of animals. Uncovering the origin of the human mind will require explaining how these unique properties came about.**

**Generative computation** enables humans to create a virtually limitless variety of words, concepts and things. The characteristic encompasses two types of operation: recursive and combinatorial. Recursion is the repeated use of a rule to create new expressions. The combinatorial operation is the mixing of discrete elements to engender new ideas.

**Promiscuous combination of ideas** allows the mingling of different domains of knowledge—such as art, sex, space, causality and friendship—thereby generating new laws, social relationships and technologies.

**Mental symbols** encode sensory experiences both real and imagined, forming the basis of a rich and complex system of communication. Such symbols can be kept to oneself or expressed to others as words or pictures.

**Abstract thought** permits contemplation of things beyond what we can see, hear, touch, taste or smell.

(“Walkman”) or musical forms, among other possibilities.

The second distinguishing characteristic of the human mind is its capacity for the promiscuous combination of ideas. We routinely connect thoughts from different domains of knowledge, allowing our understanding of art, sex, space, causality and friendship to combine. From this mingling, new laws, social relationships and technologies can result, as when we decide that it is forbidden [moral domain] to push someone [motor action domain] intentionally [folk psychology domain] in front of a train [object domain] to save the lives [moral domain] of five [number domain] others.

Third on my list of defining properties is the use of mental symbols. We can spontaneously convert any sensory experience—real or imagined—into a symbol that we can keep to ourselves or express to others through language, art, music or computer code.

Fourth, only humans engage in abstract thought. Unlike animal thoughts, which are largely anchored in sensory and perceptual experiences, many of ours have no clear connection to such events. We alone ponder the likes of unicorns and aliens, nouns and verbs, infinity and God.

Although anthropologists disagree about exactly when the modern human mind took shape, it is clear from the archaeological record that a major transformation occurred during a relatively brief period of evolutionary history, starting approximately 800,000 years ago in the Paleolithic era and crescendoing around 45,000 to 50,000 years ago. It is during this period of the Paleolithic, an evolutionary eyeblink, that we see for the first time multipart tools; animal bones punctured with holes to fashion musical instruments; burials with accoutrements suggesting beliefs about aesthetics and the afterlife; richly symbolic cave paintings that capture in exquisite detail events of the past and the perceived future; and control over fire, a technology that combines our folk physics and psychology and allowed our ancestors to prevail over novel environments by creating warmth and cooking foods to make them edible.

These remnants of our past are magnificent reminders of how our forebears struggled to solve novel environmental problems and express themselves in creative new ways, marking their unique cultural identities. Nevertheless, the archaeological evidence will forever remain silent on the origins and selective pressures that led to





GENERATIVE COMPUTATION by humans but not other animals is reflected in tool usage. Unlike other tool-using creatures, which make implements from a single material and for a single purpose, humans routinely combine materials to form tools and often use a given instrument in a number of ways. Here an orangutan employs a single leaf as an umbrella, whereas humans utilize a pencil made of several materials for a variety of purposes.



the four ingredients making up our humaniqueness. The gorgeous cave paintings at Lascaux, for instance, indicate that our ancestors understood the dual nature of pictures—that they are both objects and refer to objects and events. They do not, however, reveal whether these painters and their admirers expressed their aesthetic preferences about these artworks by means of symbols that were organized into grammatical classes (nouns, verbs, adjectives) or whether they imagined conveying these ideas equally well through sound or sign, depending on the health of their sensory systems. Similarly, none of the ancient instruments that have been found—such as the 35,000-year-old flutes made of bone and ivory—tell a story about use, about whether a few notes were played over and over again, Philip Glass-style, or about whether the composer imagined, as did Wagner, embedding themes within themes in a recursive manner.

What we can say with utmost confidence is that all people, from the hunter-gatherers on the African savanna to the traders on Wall Street, are born with the four ingredients of humaniqueness. How these ingredients are added to the recipe for creating culture varies considerably from group to group, however. Human cultures may differ in their languages, musical compositions, moral norms and artifacts. From the viewpoint of one culture, another's practices are

often bizarre, sometimes distasteful, frequently incomprehensible and occasionally immoral. No other animal exhibits such variation in lifestyle. Looked at in this way, a chimpanzee is a cultural nonstarter.

Chimps and other animals are still interesting and relevant for understanding the origins of the human mind, though. In fact, only by working out which capacities we share with other animals and which are ours alone can scientists hope to piece together the story of how our humaniqueness came to be.

## Beautiful Minds

When my youngest daughter, Sofia, was three years old, I asked her what makes us think. She pointed to her head and said: “My brain.” I then asked her whether other animals have brains, starting with dogs and monkeys and then birds and fish. She said yes. When I asked her about the

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COURTESY OF LILAN HAUSER (Hauser); JH PETE CARMICHAEL Getty Images (orangutan); PATRICK LANE Somos Images/Corbis (writing in notebook); WILLIAM WHITEHURST Corbis (pencil in hair); ALIN DRAGULIN Getty Images/Vico Collective (erasing with pencil); BRAD WILSON Getty Images (pencil in hair)

ant that was crawling in front of us, she said: “No. Too small.” We adults know that size does not provide a litmus test of whether an animal has a brain, although size does affect some aspects of brain structure and, consequently, some aspects of thought. And research has shown that most of the different cell types in the brain, along with their chemical messengers, are the same across vertebrate species, including humans. Furthermore, the general organization of the different structures in the brain’s outermost layer, the cerebral cortex, is largely the same in monkeys, apes and humans. In other words, humans have a number of brain features in common with other species. Where we differ from them is in the relative size of particular regions of the cortex and how these regions connect, differences that give rise to thoughts having no analogue elsewhere in the animal kingdom.

Animals do exhibit sophisticated behaviors that appear to presage some of our capabilities. Take, for example, the ability to create or modify objects for a particular goal. Male bowerbirds construct magnificent architectural structures from twigs and decorate them with feathers, leaves, buttons and paint made from crushed berries to attract females. New Caledonian crows carve blades into fishing sticks for catching insects. Chimpanzees have been observed to use wooden spears to shish-kebab bush babies tucked away in tree crevasses.

In addition, experimental studies in a number of animals have revealed a native folk physics that enables them to generalize beyond their direct experiences to create novel solutions when exposed to foreign challenges in the laboratory. In one such experiment, when orangutans and chimps were presented with a mounted plastic cylinder containing a peanut at the bottom, they accessed the out-of-reach treat by sipping water from their drinking fountains and then spitting the liquid into the cylinder, thus making the peanut float to the top.

Animals also exhibit social behaviors in common with humans. Knowledgeable ants teach their naive pupils by guiding them to essential food resources. Meerkats provide their pups with tutorials on the art of dismembering a lethal but delectable scorpion. And a rash of studies have shown that animals as varied as domestic dogs, capuchin monkeys and chimpanzees object to unfair distributions of food, exhibiting what economists call inequity aversion. What is more, ample evidence demonstrates that animals are not locked into their daily routines for



maintaining dominance status, caring for infants, and finding new mates and coalition partners. Rather they can readily respond to novel social situations, as when a subordinate animal with a unique skill gains favors from more dominant individuals.

These observations inspire a sense of wonder at the beauty of nature’s R&D solutions. But once we get over this frisson, we must confront the gap between humans and other species, a space that is cavernous, as our aliens reported. To fully convey the extent of this gap and the difficulty of deciphering how it arose, let me describe our humaniqueness in more detail.

## Minding the Gap

One of our most basic tools, the No. 2 pencil, used by every test taker, illustrates the exceptional freedom of the human mind as compared with the limited scope of animal cognition. You hold the painted wood, write with the lead, and erase with the pink rubber held in place by a metal ring. Four different materials, each with a particular function, all wrapped up into a single tool. And although that tool was made for writing, it can also pin hair up into a bun, bookmark a page or stab an annoying insect. Animal tools, in contrast—such as the sticks chimps use to fish termites out from their mounds—are composed of a single material, designed for a single function and never used for other functions. None have the combinatorial properties of the pencil.

Another simple tool, the telescopic, collapsible cup found in many a camper’s gear, provides



Killer whale brain  
5,620 grams



Human brain  
1,350 grams

→  
Etruscan shrew brain  
0.1 gram

## SIZING UP THE BRAIN

Humans are smarter than creatures whose brains are larger than ours in absolute terms, such as killer whales, as well as those animals whose brains are larger than ours in relative terms (that is, relative to body size), such as shrews. Thus, size alone does not explain the uniqueness of the human mind.





ANIMALS MAY USE a handful of simple utterances to represent objects and events in the present, but their range of expression is very limited compared with that of humans, whose ability to engage in abstract thought additionally enables them to discuss not only the future and past but also abstract concepts, such as the spiritual teachings of the Dalai Lama.

an example of recursion in action. To make this device, the manufacturer need only program a simple rule—add a segment of increasing size to the last segment—and repeat it until the desired size is reached. Humans use recursive operations such as this in virtually all aspects of mental life, from language, music and math to the generation of a limitless range of movements with our legs, hands and mouths. The only glimmerings of recursion in animals, however, have come from watching their motor systems in action.

All creatures are endowed with recursive motor machinery as part of their standard operating equipment. To walk, they put one foot in front of the other, over and over again. To eat, they may grasp an object and bring it to the mouth repeatedly until the stomach sends the signal to stop. In animal minds, this recursive system is locked away in the motor regions of the brain, closed off to other brain areas. Its existence suggests that a critical step in acquiring our own distinctive brand of thinking was not the evolution of recursion as a novel form of computation but the release of recursion from its motor prison to other domains of thought. How it was unlocked from this restrictive function links to one of our other ingredients—promiscuous interfaces—which I will turn to shortly.

The mental gap broadens when we compare human language with communication in other species. Like other animals, humans have a non-verbal communication system that conveys our emotions and motivations—the chortles and cries of little babies are part of this system. Hu-

mans are alone, however, in having a system of linguistic communication that is based on the manipulation of mental symbols, with each example of a symbol falling into a specific and abstract category such as noun, verb and adjective. Although some animals have sounds that appear to represent more than their emotions, conveying information about objects and events such as food, sex and predation, the range of such sounds pales in relation to our own, and none of them falls into the abstract categories that structure our linguistic expressions.

This claim requires clarification, because it often elicits extreme skepticism. You might think, for example, that animal vocabularies appear small because researchers studying their communications do not really understand what they are talking about. Although scientists have much to learn about animal vocalizations, and communication more generally, I think insufficient study is unlikely to explain the large gap. Most vocal exchanges between animals consist of one grunt or coo or scream, with a single volley back. It is possible that animals pack a vast amount of information into a 500-millisecond grunt—perhaps equivalent to “Please groom my lower back now, and I will groom yours later.” But then why would we humans have developed such an arcane and highly verbose system if we could have solved it all with a grunt or two?



**MORE THAN MATH:** Many animal species can count. But only humans can calculate the circumference of the earth, the speed of light or the likelihood of winning the lottery. In addition, we may combine our number system with various other domains of thought, such as morality, deciding whether to save five people over one, for instance.

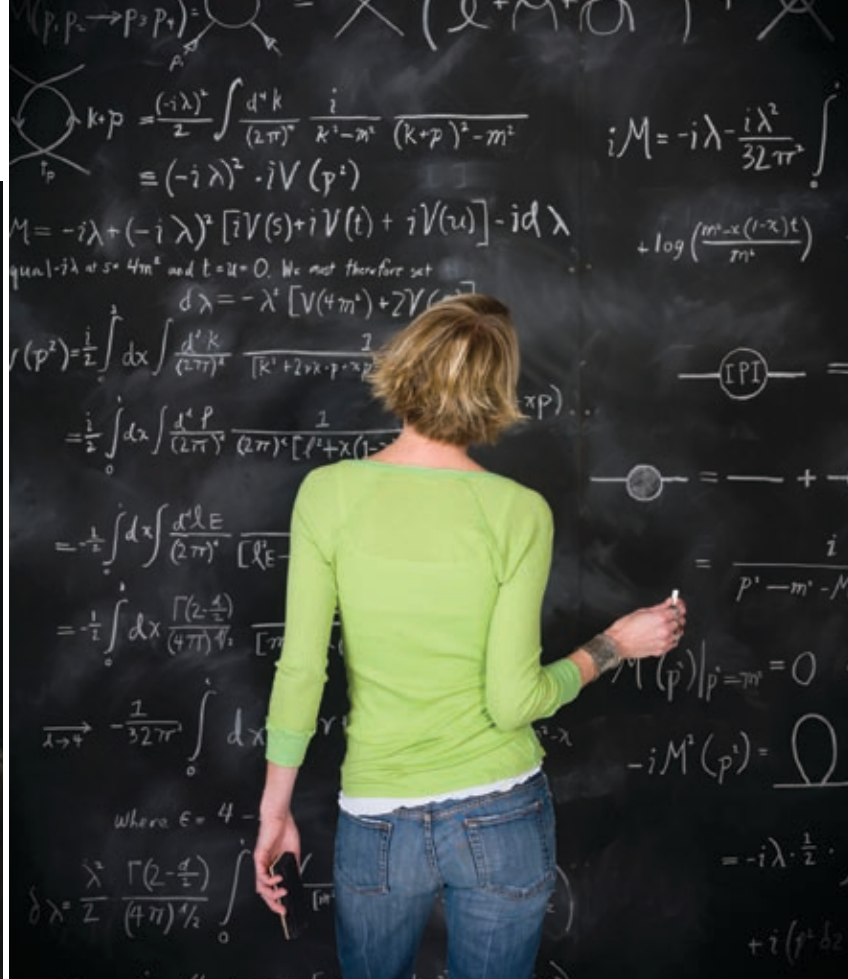
Furthermore, even if we grant that the honeybee's waggle dance symbolically represents the delicious pollen located a mile north and that the putty-nosed monkey's alarm calls symbolically represent different predators, these uses of symbols are unlike ours in five essential ways: they are triggered only by real objects or events, never imagined ones; they are restricted to the present; they are not part of a more abstract classification scheme, such as those that organize our words into nouns, verbs and adjectives; they are rarely combined with other symbols, and when they are, the combinations are limited to a string of two, with no rules; and they are fixed to particular contexts.

Human language is additionally remarkable—and entirely different from the communication systems of other animals—in that it operates equally well in the visual and auditory modes. If a songbird lost its voice and a honeybee its waggle, their communication would end. But when a human is deaf, sign language provides an equally expressive mode of communication that parallels its acoustic cousin in structural complexity.

Our linguistic knowledge, along with the computations it requires, also interacts with other domains of knowledge in fascinating ways that strikingly reflect our uniquely human abil-

ity to make promiscuous connections between systems of understanding. Consider the ability to quantify objects and events, a capacity that we share with other animals. A wide variety of species have at least two nonlinguistic abilities for counting. One is precise and limited to numbers less than four. The other is unlimited in scope, but it is approximate and limited to certain ratios for discrimination—an animal that can discriminate one from two, for instance, can also discriminate two from four, 16 from 32, and so on. The first system is anchored in a brain region involved in keeping track of individuals, whereas the second is anchored in brain regions that compute magnitudes.

Last year my colleagues and I described a third counting system in rhesus monkeys, one that may help us understand the origins of the human ability to mark the difference between singular and plural. This system operates when individuals see sets of objects presented at the same time—as opposed to individuals presented serially—and causes rhesus monkeys to discriminate one from many but not many from many food items. In our experiment, we showed a rhesus monkey one apple and placed it in a box. We then showed the same monkey five apples and placed all five at once into a second box. Given a choice the monkey consistently picked the second



TIM FLACH/Getty Images (macaque); RICHARD SCHULTZ Corbis (woman at blackboard)



box with five apples. Then we put two apples in one box and five into the other. This time the monkey did not show a consistent preference. We humans do essentially the same thing when we say “one apple” and “two, five or 100 apples.”

But something peculiar happens when the human linguistic system connects up with this more ancient conceptual system. To see how, try this exercise: for the numbers 0, 0.2 and  $-5$ , add the most appropriate word: “apple” or “apples.” If you are like most native English speakers, including young children, you selected “apples.” In fact, you would select “apples” for “1.0.” If you are surprised, good, you should be. This is not a rule we learned in grammar school—in fact, strictly speaking, it is not grammatically correct. But it is part of the universal grammar that we alone are born with. The rule is simple but abstract: anything that is not “1” is pluralized.

The apple example demonstrates how different systems—syntax and concepts of sets—interact to produce new ways of thinking about or conceptualizing the world. But the creative process in humans does not stop here. We apply our language and number systems to cases of morality (saving five people is better than saving one), economics (if I am giving \$10 and offer you \$1, that seems unfair, and you will reject the dollar), and taboo trade-offs (in the U.S., selling our children, even for lots of money, is not kosher).

## Alien Thoughts

From didactic meerkats to inequity-averse monkeys, the same observation applies: each of these animals has evolved an exquisite mind that is adapted to singular problems and is thus limited when it comes to applying skills to novel problems. Not so for us hairless bipeds. Once in place, the modern mind enabled our forebears to explore previously uninhabited parts of the earth, to create language to describe novel events, and to envision an afterlife.

The roots of our cognitive abilities remain largely unknown, but having pinpointed the unique ingredients of the human mind, scientists now know what to look for. To that end, I am hopeful that neurobiology will prove illuminating. Although scholars do not yet understand how genes build brains and how electrical activity in the brain builds thoughts and emotions, we are witnessing a revolution in the sciences of the mind that will fill in these blanks—and enrich our understanding of why the human brain differs so profoundly from those of other creatures.

For instance, studies of chimeric animals—in which brain circuits from an individual of one species are transplanted into an individual of another species—are helping to unravel how the brain is wired. And experiments with genetically modified animals are revealing genes that play roles in language and other social processes. Such achievements do not reveal anything about what our nerve cells do to give us our unique mental powers, but they do provide a roadmap for further exploration of these traits.

Still, for now, we have little choice but to admit that our mind is very different from that of even our closest primate relatives and that we do not know much about how that difference came to be. Could a chimpanzee think up an experiment to test humans? Could a chimpanzee imagine what it would be like for us to solve one of their problems? No and no. Although chimpanzees can see what we do, they cannot imagine what we think or feel because they lack the requisite mental machinery. Although chimpanzees and other animals appear to develop plans and consider both past experiences and future options, there is no evidence that they think in terms of counterfactuals—imagining worlds that have been against those that could be. We humans do this all the time and have done so ever since our distinctive genome gave birth to our distinctive minds. Our moral systems are premised on this mental capacity.

Have our unique minds become as powerful as a mind can be? For every form of human expression—including the world’s languages, musical compositions, moral norms and technological forms—I suspect we are unable to exhaust the space of all possibilities. There are significant limitations to our ability to imagine alternatives.

If our minds face inherent constraints on what they can conceive, then the notion of “thinking outside of the box” is all wrong. We are always inside the box, limited in our capacity to envision alternatives. Thus, in the same way that chimpanzees cannot imagine what it is like to be human, humans cannot imagine what it is like to be an intelligent alien. Whenever we try, we are stuck in the box that we call the human mind. The only way out is through evolution, the revolutionary remodeling of our genome and its potential to sculpt fresh neural connections and fashion new neural structures. Such change would give birth to a novel mind, one that would look on its ancestors as we often look on ours: with respect, curiosity, and a sense that we are alone, paragons in a world of simple minds. ■

IVORY BIRD SCULPTURE ▲

## LIMITED CLUES

The archaeological record reveals that humans were routinely making art and musical instruments by 35,000 years ago, indicating that they were thinking symbolically by then. But modern scholars have no way of knowing what these long-ago people thought about the symbols they left behind nor how they composed their music. Such artifacts are thus of limited use in piecing together the origins of our unique mental abilities.

BIRD BONE FLUTE ▼



## ➔ MORE TO EXPLORE

**The Faculty of Language: What Is It, Who Has It, and How Did It Evolve?** Marc D. Hauser, Noam Chomsky and W. Tecumseh Fitch in *Science*, Vol. 298, pages 1569–1579; November 22, 2002.

**Moral Minds: How Nature Designed Our Universal Sense of Right and Wrong.** Marc D. Hauser. Harper Collins, 2006.

**Baboon Metaphysics: The Evolution of a Social Mind.** Dorothy L. Cheney and Robert M. Seyfarth. University of Chicago Press, 2007.