

ARE WE
SMART ENOUGH
TO KNOW
HOW SMART
ANIMALS ARE?

Frans de Waal

With drawings by the author

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of species together by an absence, as if they were missing something. Poor things, they are nonhuman! When students embrace this jargon in their writing, I cannot resist sarcastic corrections in the margin saying that for completeness's sake, they should add that the animals they are talking about are also nonpenguin, nonhyena, and a whole lot more.

Even though comparative psychology is changing for the better, I'd rather avoid its leaden baggage and propose to call the new field *evolutionary cognition*, which is the study of all cognition (human and animal) from an evolutionary standpoint. Which species we study obviously matters a great deal, and humans are not necessarily central to every comparison. The field includes phylogeny, when we trace traits across the evolutionary tree to determine whether similarities are due to common descent, the way Lorenz had done so beautifully for waterfowl. We also ask how cognition has been shaped to serve survival. The agenda of this field is precisely what Griffin and Uexküll had in mind, in that it seeks to place the study of cognition on a less anthropocentric footing. Uexküll urged us to look at the world from the animal's standpoint, saying that this is the only way to fully appreciate animal intelligence.

A century later we are ready to listen.

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A TALE OF TWO SCHOOLS

Do Dogs Desire?

Given the prominent role that jackdaws and little silvery fish known as three-spined sticklebacks—my favorite childhood animals—played in the early years of ethology, the discipline was an easy sell to me. I learned about it when, as a biology student, I heard a professor explain the zigzag dance of the stickleback. I was floored: not by what these little fish did but by how seriously science took what they did. It was the first time I realized that what I liked doing best—watching animals behave—could be a profession. As a boy, I had spent hours observing self-caught aquatic life that I kept in buckets and tanks in our backyard. The high point had been breeding sticklebacks and releasing the young back into the ditch from which their parents had come.

Ethology is the biological study of animal behavior that arose in continental Europe right before and after World War II. It reached the English-speaking world when one of its founders, Niko Tinbergen, moved across the Channel. A Dutch zoologist, Tinbergen started out in Leiden and accepted a position in Oxford in 1949. He described the male stickleback's zigzag dance in great detail, explaining how it draws the female to the nest where the male fertilizes her eggs. The male then

we do when we name a hurricane after a person or curse our computer as if it had free will.

The key point is that anthropomorphism is not always as problematic as people think. To rail against it for the sake of scientific objectivity often hides a pre-Darwinian mindset, one uncomfortable with the notion of humans as animals. When we are considering species like the apes, which are aptly known as “anthropoids” (humanlike), however, anthropomorphism is in fact a logical choice. Dubbing an ape’s kiss “mouth-to-mouth contact” so as to avoid anthropomorphism deliberately obfuscates the meaning of the behavior. It would be like assigning Earth’s gravity a different name than the moon’s, just because we think Earth is special. Unjustified linguistic barriers fragment the unity with which nature presents us. Apes and humans did not have enough time to independently evolve strikingly similar behavior, such as lip contact in greeting or noisy breathing in response to tickling. Our terminology should honor the obvious evolutionary connections.

On the other hand, anthropomorphism would be a rather empty exercise if all it did was paste human labels onto animal behavior. The American biologist and herpetologist Gordon Burghardt has called for a *critical anthropomorphism*, in which we use human intuition and knowledge of an animal’s natural history to formulate research questions.²³ Thus, saying that animals “plan” for the future or “reconcile” after fights is more than anthropomorphic language: these terms propose testable ideas. If primates are capable of planning, for example, they should hold on to a tool that they can use only in the future. And if primates reconcile after fights, we should see a reduction of tensions as well as improved social relationships after opponents have made up by means of friendly contact. These obvious predictions have by now been borne out by actual experiments and observations.²⁴ Serving as a means rather than an end, critical anthropomorphism is a valuable source of hypotheses.

Griffin’s proposal to take animal cognition seriously led to a new label for this field: *cognitive ethology*. It is a great label, but then I am an ethol-

ogist and know exactly what he meant. Unfortunately, the term *ethology* has not universally caught on, and spell-checkers still regularly change it to *ethnology*, *etiology*, or even *theology*. No wonder many ethologists nowadays call themselves behavioral biologists. Other existing labels for cognitive ethology are *animal cognition* and *comparative cognition*. But those two terms have drawbacks, too. *Animal cognition* fails to include humans, so it unintentionally perpetuates the idea of a gap between humans and other animals. The *comparative* label, on the other hand, remains agnostic about how and why we make comparisons. It hints at no framework whatsoever to interpret similarities and differences, least of all an evolutionary one. Even within this discipline, there have been complaints about its lack of theory as well as its habit of dividing animals into “higher” and “lower” forms.²⁵ The label derives from *comparative psychology*, the name of a field that traditionally has viewed animals as mere stand-ins for humans: a monkey is a simplified human, a rat a simplified monkey, and so on. Since associative learning was thought to explain behavior across all species, one of the field’s founders, B. F. Skinner, felt that it hardly mattered what kind of animal one worked on.²⁶ To prove his point, he entitled a book entirely devoted to albino rats and pigeons *The Behavior of Organisms*.

For these reasons, Lorenz once joked that there was nothing comparative about comparative psychology. He knew what he was talking about, having just published a seminal study on the courtship patterns of twenty different duck species.²⁷ His sensitivity to the minutest differences between species was quite the opposite of the way comparative psychologists lump animals together as “nonhuman models of human behavior.” Think for a second about this terminology, which remains so entrenched in psychology that no one takes notice anymore. Its first implication, of course, is that the only reason to study animals is to learn about ourselves. Second, it ignores that every species is uniquely adapted to its own ecology, because otherwise how could one serve as a model for another? Even the term *nonhuman* grates on me, since it lumps millions



Ape gestures are homologous with those of humans. Not only do they look strikingly human, they occur in roughly similar contexts. Here a female chimpanzee (right) kisses a grizzled alpha male on the mouth during a reconciliation after a fight between them.

Griffin said, echoing Charles Darwin's well-known observation that the mental difference between humans and other animals is one of degree rather than kind.

It was an honor to get to know this kindred spirit and to make my own case regarding anthropomorphism, another theme at the conference. Greek for "human form," the word *anthropomorphism* came about when Xenophanes, in 570 B.C., objected to Homer's poetry because it described the gods as if they looked like people. Xenophanes ridiculed the arrogance behind this assumption—why couldn't they look like horses? But gods are gods, far removed from the present-day liberal use of the word *anthropomorphism* as an epithet to vilify any and all human-animal comparisons, even the most cautious ones.

In my opinion, anthropomorphism is problematic only when the human-animal comparison is a stretch, such as with regards to species distant from us. The fish known as kissing gouramis, for example, don't

really kiss in the same way and for the same reasons that humans do. Adult fish sometimes lock their protruding mouths together to settle disputes. Clearly, to label this habit "kissing" is misleading. Apes, on the other hand, do greet each other after a separation by placing their lips gently on each other's mouth or shoulder and hence kiss in a way and under circumstances that greatly resemble human kissing. Bonobos go even further: when a zookeeper familiar with chimpanzees once naïvely accepted a bonobo kiss, not knowing this species, he was taken aback by the amount of tongue that went into it!

Another example: when young apes are being tickled, they make breathy sounds with a rhythm of inhalation and exhalation that resembles human laughter. One cannot simply dismiss the term *laughter* for this behavior as too anthropomorphic (as some have done), because not only do the apes sound like human children being tickled, they show the same ambivalence about it as children do. I have often noticed it myself. They try to push my tickling fingers away, but then come back begging for more, holding their breath while awaiting the next poke in their belly. In this case, I am all for shifting the burden of proof and ask those who wish to avoid humanlike terminology to first prove that a tickled ape, who almost chokes on its hoarse giggles, is in fact in a different state of mind from a tickled human child. Absent such evidence, *laughter* strikes me as the best label for both.²¹

Needing a new term to make my point, I invented *anthropodenial*, which is the a priori rejection of humanlike traits in other animals or animallike traits in us. Anthropomorphism and anthropodenial have an inverse relationship: the closer another species is to us, the more anthropomorphism will assist our understanding of this species and the greater will be the danger of anthropodenial.²² Conversely, the more distant a species is from us, the greater the risk that anthropomorphism will propose questionable similarities that have come about independently. Saying that ants have "queens," "soldiers," and "slaves" is mere anthropomorphic shorthand. We should attach no more significance to it than

ize ourselves with all facets of the animal and its natural history before trying to figure out its mental level. And instead of testing animals on abilities that *we* are particularly good at—our own species' magic wells, such as language—why not test them on *their* specialized skills? In doing so, we will not just flatten Aristotle's scale of nature: we will transform it into a bush with many branches. This change in perspective is now feeding the long-overdue recognition that intelligent life is not something we must seek at great expense only in the outer reaches of space. It is abundant here on earth, right underneath our nonprehensile noses.¹⁸

Anthropodenial

The ancient Greeks believed that the center of the universe was right where they lived. What better place, therefore, than Greece for modern scholars to ponder humanity's place in the cosmos? On a sunny day in 1996, an international group of academics visited the *omphalos* (navel) of the world—a large stone shaped like a beehive—amid the temple ruins on Mount Parnassus. I couldn't resist patting it like a long-lost friend. Right next to me stood "batman" Don Griffin, the discoverer of echolocation and author of *The Question of Animal Awareness*, in which he lamented the misperception that everything in the world turns around us and that we are the only conscious beings.¹⁹

Ironically, a major theme of our workshop was the anthropic principle, according to which the universe is a purposeful creation uniquely suited for intelligent life, meaning us.²⁰ At times the discourse of the anthropic philosophers sounded as if they thought the world was made for us rather than the other way around. Planet Earth is at exactly the right distance from the sun to create the right temperature for human life, and its atmosphere has the ideal oxygen level. How convenient! Instead of seeing purpose in this situation, however, any biologist will turn the causal connection around and note that our species is finely adapted to the planet's circumstances, which explains why they are per-

fect for us. Deep ocean vents are an optimal environment for bacteria thriving on their superhot sulfuric output, but no one assumes that these vents were created to serve thermophile bacteria; rather, we understand that natural selection has shaped bacteria able to live near them.

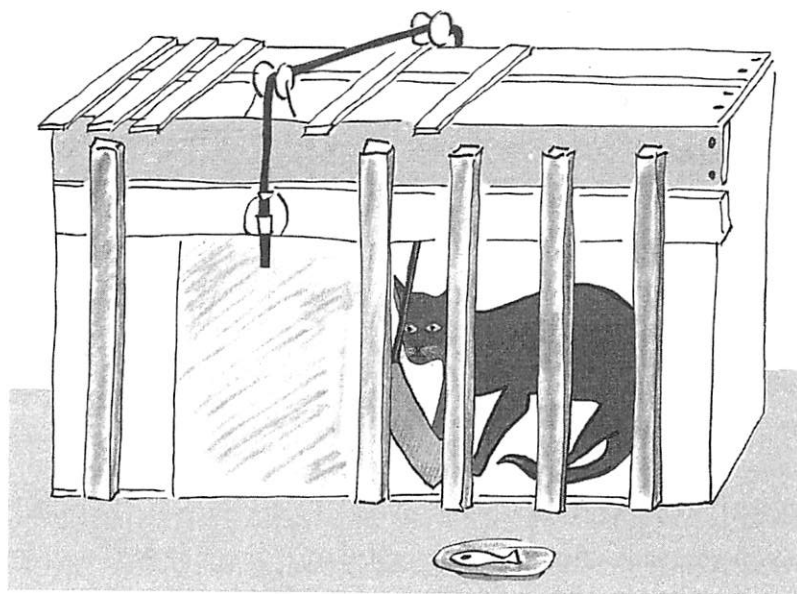
The backward logic of these philosophers reminded me of a creationist I once saw peel a banana on television while explaining that this fruit is curved in such a way that it conveniently angles toward the human mouth when we hold it in our hand. It also fits perfectly in our mouth. Obviously, he felt that God had given the banana its human-friendly shape, while forgetting that he was holding a domesticated fruit, cultivated for human consumption.

During some of these discussions, Don Griffin and I watched barn swallows flying back and forth outside the conference room window carrying mouthfuls of mud for their nests. Griffin was at least three decades my senior and had impressive knowledge, offering the Latin name of the birds and describing details of their incubation period. At the workshop, he presented his view on consciousness: that it has to be part and parcel of all cognitive processes, including those of animals. My own position is slightly different in that I prefer not to make any firm statements about something as poorly defined as consciousness. No one seems to know what it is. But for the same reason, I hasten to add, I'd never deny it to any species. For all I know, a frog may be conscious. Griffin took a more positive stance, saying that since intentional, intelligent actions are observable in many animals, and since in our own species they go together with awareness, it is reasonable to assume similar mental states in other species.

That such a highly respected and accomplished scientist made this claim had a hugely liberating effect. Even though Griffin was slammed for making statements that he could not back up with data, many critics missed the point, which was that the assumption that animals are "dumb," in the sense that they lack conscious minds, is only that: an assumption. It is far more logical to assume continuity in every domain,

*a way that appears extremely flighty and unscientific to some thinkers who place value on strictly logical sequences—and one's knowledge of each of the parts must advance at the same pace.*¹⁵

The danger of ignoring this advice was amusingly illustrated when a famous study was replicated. In the study, domestic cats were placed in a small cage; they would wander about impatiently meowing—and in the process rub against the cage interior. In so doing, they accidentally moved a latch that opened a door, which allowed them to get out of the cage and eat a scrap of fish nearby. The more trials a cat performed, the quicker she'd escape. The investigators were impressed that all the tested cats showed the same stereotyped rubbing pattern, which they thought they had taught them with food rewards. First developed by



Edward Thorndike's cats were considered to have proven the "law of effect." By rubbing against a latch inside a cage, a cat could open a door and escape, which would gain her a fish. Decades later, however, it was shown that the cats' behavior had nothing to do with the prospect of reward. The animals escaped just as well without the fish. The presence of friendly people was all that was needed to elicit the flank rubbing that marks all feline greeting behavior. After Thorndike (1898).

Edward Thorndike in 1898, this experiment was considered proof that even seemingly intelligent behavior (such as escaping from a cage) can be fully explained by trial-and-error learning. It was a triumph of the "law of effect," according to which behavior with pleasant consequences is likely to be repeated.¹⁶

When the American psychologists Bruce Moore and Susan Stutard replicated this study decades later, however, they found that the cats' behavior was nothing special. The cats performed the usual *Köpfcchengeben* (German for "head giving") that all felines—from house cats to tigers—use in greeting and courting. They rub their head or flank against the object of affection or, if the object of affection is inaccessible, redirect the rubbing to inanimate objects, such as the legs of a kitchen table. The investigators showed that the food reward was not needed: the only meaningful factor was the presence of friendly people. Without training, every caged cat that saw a human observer rubbed its head, flank, and tail against the latch and got out of the cage. Left alone, however, the cats were unable to escape, since they never performed any rubbing.¹⁷ Instead of a learning experiment, the classical study had been a greeting experiment! The replication was published under the telling subtitle "Tripping over the Cat."

The lesson is that before scientists test any animal, they need to know its typical behavior. The power of conditioning is not in doubt, but the early investigators had totally overlooked a crucial piece of information. They had not, as recommended by Lorenz, considered the whole organism. Animals show many unconditioned responses, or behavior that develops naturally in all members of their species. Reward and punishment may affect such behavior but cannot take credit creating it. The reason all cats responded in the same way derived from natural feline communication rather than operant conditioning.

The field of evolutionary cognition requires us to consider every species in full. Whether we are studying hand anatomy, trunk multifunctionality, face perception, or greeting rituals, we need to familiar-

to find out what the mirror was all about, but if the wall had collapsed, we might have ended up chasing elephants in New York traffic! Fortunately, the wall held, and the animals got used to the mirror.

One Asian elephant, named Happy, recognized her reflection. Marked with a white cross on her forehead above her left eye, she repeatedly rubbed the mark while standing in front of the mirror. She connected her reflection with her own body.¹² By now, years later, Josh has tested many more animals at Think Elephants International, in Thailand, and our conclusion holds: some Asian elephants recognize themselves in the mirror. Whether the same can be said of African elephants is hard to tell, because up to now our experiments have resulted in a lot of destroyed mirrors due to this species' tendency to examine new items with vigorous tusk action. This makes it hard to decide between poor performance and poor equipment. Obviously, the destruction of mirrors is no reason to conclude that African elephants lack mirror self-recognition. We are just dealing with species-typical treatment of novel items.

The challenge is to find tests that fit an animal's temperament, interests, anatomy, and sensory capacities. Faced with negative outcomes, we need to pay close attention to differences in motivation and attention. One cannot expect a great performance on a task that fails to arouse interest. We ran into this problem while studying face recognition in chimpanzees. At the time, science had declared humans unique, since we were so much better at identifying faces than any other primate. No one seemed bothered by the fact that other primates had been tested mostly on human faces rather than those of their own kind. When I asked one of the pioneers in this field why the methodology had never moved beyond the human face, he answered that since humans differ so strikingly from one another, a primate that fails to tell members of our species apart will surely also fail at its own kind.

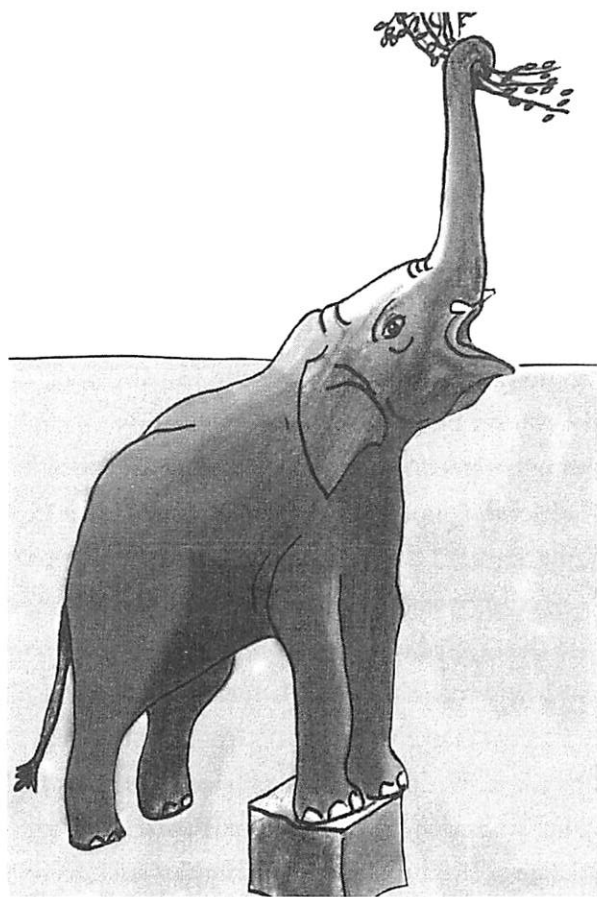
But when Lisa Parr, one of my coworkers at the Yerkes National

Primate Research Center in Atlanta, tested chimpanzees on photographs of their own species, she found that they excelled at it. Selecting images on a computer screen, they would see one chimpanzee portrait immediately followed by a pair of others. One portrait of the pair would be a different picture of the same individual as presented before, while the other would show a different individual. Having been trained to detect similarity (a procedure known as matching to sample), the chimpanzees had no trouble recognizing which portrait most resembled the first. The apes even detected family ties. After having seen a female portrait, they were given a choice between two juvenile faces, one of which was the offspring of the female shown before. They picked the latter based purely on physical similarity, since they did not know any of the depicted apes in real life.¹³ In much the same way, we can leaf through someone else's family album and quickly notice who are blood relatives and who are in-laws. As it turns out, chimpanzee face recognition is as keen as ours. It is now widely accepted as a shared capacity, especially since it engages the same brain areas in humans and other primates.¹⁴

In other words, what is salient to us—such as our own facial features—may not be salient to other species. Animals often know only what they *need* to know. The maestro of observation, Konrad Lorenz, believed that one could not investigate animals effectively without an intuitive understanding grounded in love and respect. He saw such intuitive insight as quite separate from the methodology of the natural sciences. To marry it productively with systematic research is both the challenge and the joy of studying animals. Promoting what he called the *Ganzheitsbetrachtung* (holistic contemplation), Lorenz urged us to grasp the whole animal before zooming in on its various parts.

One cannot master set research tasks if one makes a single part the focus of interest. One must, rather, continuously dart from one part to another—in

On a visit to the National Zoo in Washington, D.C., I met Preston Foerder and Diana Reiss, who showed me what Kandula, a young elephant bull, can do when the problem is presented differently. The scientists hung fruit high up above Kandula's enclosure, just out of his reach. They gave the elephant several sticks and a sturdy square box. Kandula ignored the sticks but, after a while, began kicking the box with his foot. He kicked it many times in a straight line until it was right underneath



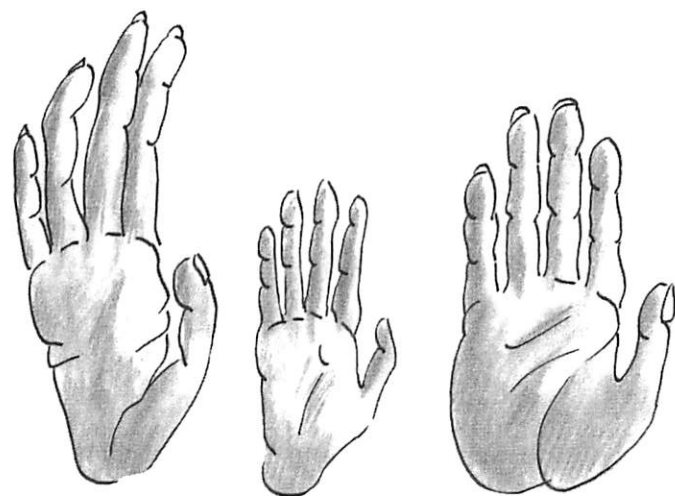
Elephants were believed to be inept tool users based on the assumption that they should use their trunk. In a tool task that bypassed the trunk, however, Kandula had no trouble reaching green branches hanging high above his head. He went out of his way to fetch a box to stand on.

the fruit. He then stood on the box with his front legs, which enabled him to reach the food with his trunk. An elephant, it turns out, can use tools—if they are the right ones.

As Kandula munched his reward, the investigators explained to me how they had varied the setup, making life more difficult for the elephant. They had put the box in a different section of the yard, out of view, so that when Kandula looked up at the tempting food, he would need to recall the solution while distancing himself from his goal to fetch the tool. Apart from a few large-brained species, such as humans, apes, and dolphins, not many animals will do this, but Kandula did it without hesitation, fetching the box from great distances.¹⁰

Clearly, the scientists had found a species-appropriate test. In search of such methods, even something as simple as size can matter. The largest land animal cannot always be tested with human-sized tools. In one experiment researchers conducted a mirror test—to evaluate whether an animal recognizes its own reflection. They placed a mirror on the floor outside an elephant cage. Measuring only 41 by 95 inches, it was angled up so that the elephant probably mostly saw its legs moving behind two layers of bars (since the mirror doubled them). When the elephant received a body mark that was visible only with assistance of the mirror, it failed to touch it. The verdict was that the species lacked self-awareness.¹¹

But Joshua Plotnik, then a student of mine, modified the test. He gave elephants at the Bronx Zoo access to an eight-foot-square mirror placed directly inside their enclosure. They could feel it, smell it, and look behind it. Close-up exploration is a critical step, for apes and humans as well; that had been impossible in the earlier study. In fact, the elephants' curiosity worried us, as the mirror was mounted on a wooden wall that was not designed to support climbing pachyderms. Elephants normally don't stand up against structures, so having a four-ton animal lean on a flimsy wall in order to see and smell what was behind the mounted mirror scared us to death. Clearly, the animals were motivated



Gibbon

Macaque

Human

The gibbon's hand lacks a fully opposable thumb. It is suited for grasping branches rather than for picking up items from a flat surface. Only when their hand morphology was taken into account did gibbons pass certain intelligence tests. Here a comparison between the hands of a gibbon, a macaque, and a human. After Benjamin Beck (1967).

required them to choose between various cups, strings, and sticks. In test after test, these primates fared poorly compared to other species. Tool use, for example, was tested by dropping a banana outside their cage and placing a stick nearby. All they had to do to get the banana was pick up the stick to move it closer. Chimpanzees will do so without hesitation, as will many manipulative monkeys. But not gibbons. This was bizarre given that gibbons (also known as “lesser apes”) belong to the same large-brained family as humans and apes.

In the 1960s an American primatologist, Benjamin Beck, took a fresh approach.⁹ Gibbons are exclusively arboreal. Known as *brachiators*, they propel themselves through trees by hanging by their arms and hands. Their hands, which have tiny thumbs and elongated fingers, are specialized for this kind of locomotion: gibbon hands act more like hooks than like the versatile grasping and feeling organs of most other primates.

Beck, realizing that the gibbon's *Umwelt* barely includes the ground level and that its hands make it impossible to pick up objects from a flat surface, redesigned a traditional string-pulling task. Instead of presenting strings lying on a surface, as had been done before, he elevated them to the animal's shoulder level, making them easier to grasp. Without going into detail—the task required the animal to look carefully at how a string was attached to food—the gibbons solved all the problems quickly and efficiently, demonstrating the same intelligence as other apes. Their earlier poor performance had had more to do with the way they were tested than with their mental powers.

Elephants are another good example. For years, scientists believed them incapable of using tools. The pachyderms failed the same out-of-reach banana test, leaving the stick alone. Their failure could not be attributed to an inability to lift objects from a flat surface, because elephants are ground dwellers and pick up items all the time, sometimes tiny ones. Researchers concluded that they just didn't get the problem. It occurred to no one that perhaps we, the investigators, didn't get the elephant. Like the six blind men, we keep turning around and poking the big beast, but we need to remember that, as Werner Heisenberg put it, “what we observe is not nature in itself, but nature exposed to our method of questioning.” Heisenberg, a German physicist, made this observation regarding quantum mechanics, but it holds equally true for explorations of the animal mind.

In contrast to the primate's hand, the elephant's grasping organ is also its nose. Elephants use their trunks not only to reach food but also to sniff and touch it. With their unparalleled sense of smell, these animals know exactly what they are going for. But picking up a stick blocks their nasal passages. Even when they bring the stick close to the food, it impedes their feeling and smelling it. It is like sending a blindfolded child out on an Easter egg hunt.

What sort of experiment, then, would do justice to the animal's special anatomy and abilities?

ble each other most, joke about each other. The Dutch find nothing to laugh at in the Chinese or the Brazilians, but they relish a good joke about the Belgians.

But why stop at the primates when we are considering cognition? Every species deals flexibly with the environment and develops solutions to the problems it poses. Each one does it differently. We had better use the plural to refer to their capacities, therefore, and speak of intelligences and cognitions. This will help us avoid comparing cognition on a single scale modeled after Aristotle's *scala naturae*, which runs from God, the angels, and humans at the top, downward to other mammals, birds, fish, insects, and mollusks at the bottom. Comparisons up and down this vast ladder have been a popular pastime of cognitive science, but I cannot think of a single profound insight it has yielded. All it has done is make us measure animals by human standards, thus ignoring the immense variation in organisms' *Umwelten*. It seems highly unfair to ask if a squirrel can count to ten if counting is not really what a squirrel's life is about. The squirrel is very good at retrieving hidden nuts, though, and some birds are absolute experts. The Clark's nutcracker, in the fall, stores more than twenty thousand pine nuts, in hundreds of different locations distributed over many square miles; then in winter and spring it manages to recover the majority of them.⁷

That we can't compete with squirrels and nutcrackers on this task—I even forget where I parked my car—is irrelevant, since our species does not need this kind of memory for survival the way forest animals braving a freezing winter do. We don't need echolocation to orient ourselves in the dark; nor do we need to correct for the refraction of light between air and water as archerfish do while shooting droplets at insects above the surface. There are lots of wonderful cognitive adaptations out there that we don't have or need. This is why ranking cognition on a single dimension is a pointless exercise. Cognitive evolution is marked by many peaks of specialization. The ecology of each species is key.

The last century has seen ever more attempts to enter the *Umwelt* of

other species, reflected in book titles such as *The Herring Gull's World*, *The Soul of the Ape*, *How Monkeys See the World*, *Inside a Dog*, and *Anthill*, in which E. O. Wilson, in his inimitable fashion, offers an ant's-eye view of the social life and epic battles of ants.⁸ Following in the footsteps of Kafka and Uexküll, we are trying to get under the skin of other species, trying to understand them on their terms. And the more we succeed, the more we discover a natural landscape dotted with magic wells.

Six Blind Men and the Elephant

Cognition research is more about the possible than the impossible. Nevertheless, the *scala naturae* view has tempted many to conclude that animals lack certain cognitive capacities. We hear abundant claims along the lines of "only humans can do this or that," referring to anything from looking into the future (only humans think ahead) and being concerned for others (only humans care about the well-being of others) to taking a vacation (only humans know leisure time). The last claim once had me, to my own amazement, debating a philosopher in a Dutch newspaper about the difference between a tourist tanning on the beach and a napping elephant seal. The philosopher considered the two to be radically different.

In fact, I find the best and most enduring claims about human exceptionalism to be the funny ones, such as Mark Twain's "Man is the only animal that blushes—or needs to." But, of course, most of these claims are deadly serious and self-congratulatory. The list goes on and on and changes every decade, yet must be treated with suspicion given how hard it is to prove a negative. The credo of experimental science remains that an absence of evidence is not evidence of absence. If we fail to find a capacity in a given species, our first thought ought to be "Did we overlook something?" And the second should be "Did our test fit the species?"

A telling illustration involves gibbons, which were once considered backward primates. Gibbons were presented with problems that

location of bats, which had been discovered only because scientists did try to imagine what it is like to be a bat and did in fact succeed. It is one of the triumphs of our species' thinking outside its perceptual box.

As a student, I listened in amazement as Sven Dijkgraaf, the head of my department at the University of Utrecht, told the story of how, at about my age, he was one of only a handful of people in the world who was able to hear the faint clicks that accompany a bat's ultrasonic vocalizations. The professor had extraordinary hearing. It had been known for more than a century that a blinded bat can still find its way around and safely land on walls and ceilings, whereas a deafened one cannot. A bat without hearing is like a human without sight. No one fully understood how this worked, and bats' abilities were unhelpfully attributed to a "sixth sense." Scientists don't believe in extrasensory perception, however, and Dijkgraaf had to come up with an alternative explanation. Since he could detect a bat's calls, and had noticed that the rate increased when bats encountered obstacles, he suggested that the calls help them traverse their environment. But there was always a tone of regret in his voice about the lack of recognition he had received as the discoverer of echolocation.

This honor had gone to Donald Griffin, and rightly so. Assisted by equipment that could detect sound waves above the 20 kHz range of human hearing, this American ethologist had conducted the ultimate experiments, which furthermore demonstrated that echolocation is more than just a collision warning system. Ultrasound serves to find and pursue prey, from large moths to little flies. Bats possess an astonishingly versatile hunting tool.

No wonder Griffin became an early champion of animal cognition—a term considered an oxymoron until well into the 1980s—because what else is cognition but information processing? *Cognition* is the mental transformation of sensory input into knowledge about the environment and the flexible application of this knowledge. While the term *cognition*

refers to the process of doing this, *intelligence* refers more to the ability to do it successfully. The bat works with plenty of sensory input, even if it remains alien to us. Its auditory cortex evaluates sounds bouncing off objects, then uses this information to calculate its distance to the target as well as the target's movement and speed. As if this weren't complex enough, the bat also corrects for its own flight path and distinguishes the echoes of its own vocalizations from those of nearby bats: a form of self-recognition. When insects evolved hearing in order to evade bat detection, some bats responded with "stealth" vocalizations below the hearing level of their prey.

What we have here is a most sophisticated information-processing system backed by a specialized brain that turns echoes into precise perception. Griffin had followed in the footsteps of the pioneering experimentalist Karl von Frisch, who had discovered that honeybees use a waggle dance to communicate distant food locations. Von Frisch once said, "The life of the bee is like a magic well, the more you draw from it, the more there is to draw."⁵ Griffin felt the same about echolocation, seeing this capacity as yet another inexhaustible source of mystery and wonder. He called it, too, a magic well.⁶

Since I work with chimpanzees, bonobos, and other primates, people usually don't give me a hard time when I speak of cognition. After all, people are primates, too, and we process our surroundings in similar ways. With our stereoscopic vision, grasping hands, ability to climb and jump, and emotional communication via facial muscles, we inhabit the same *Umwelt* as other primates. Our children play on "monkey bars," and we call imitation "aping," precisely because we recognize these similarities. At the same time, we feel threatened by primates. We laugh hysterically at apes in movies and sitcoms, not because they are inherently funny—there are much funnier-looking animals, such as giraffes and ostriches—but because we like to keep our fellow primates at arm's length. It is similar to how people in neighboring countries, who resem-

butyric acid emanating from mammalian skin. Since experiments have shown that this arachnid can go for eighteen years without food, the tick has ample time to meet a mammal, drop onto her victim, and gorge herself on warm blood. Afterward she is ready to lay her eggs and die. Can we understand the tick's *Umwelt*? It seems incredibly impoverished compared to ours, but Uexküll saw its simplicity as a strength: her goal is well defined, and she encounters few distractions.

Uexküll reviewed other examples, showing that a single environment offers hundreds of realities peculiar to each species. *Umwelt* is quite different from the notion of *ecological niche*, which concerns the habitat that an organism needs for survival. Instead, *Umwelt* stresses an organism's self-centered, subjective world, which represents only a small tranche of all available worlds. According to Uexküll, the various tranches are "not comprehended and never discernible" to all the species that construct them.² Some animals perceive ultraviolet light, for example, while others live in a world of smells or, like the star-nosed mole, feel their way around underground. Some sit on the branches of an oak, and others live underneath its bark, while a fox family digs a lair among its roots. Each perceives the same tree differently.

Humans can try to imagine the *Umwelt* of other organisms. Being a highly visual species ourselves, we buy smartphone apps that turn colorful images into those seen by people without color vision. We can walk around blindfolded to simulate the *Umwelt* of the vision-impaired in order to augment our empathy. My most memorable experience with an alien world, however, came from raising jackdaws, small members of the crow family. Two of them flew in and out of my window on the fourth floor of a student dorm, so I could watch their exploits from above. When they were young and inexperienced, I observed them, like any good parent, with great apprehension. We think of flight as something birds do naturally, but it is actually a skill that they have to learn. Landing is the hardest part, and I was always afraid they would crash

into a moving car. I began to think like a bird, mapping the environment as if looking for the perfect landing spot, judging a distant object (a branch, a balcony) with this goal in mind. Upon achieving a safe landing, my birds would give happy "caw-caw" calls, after which I would call them to come back, and the whole process would start anew. Once they became expert flyers, I enjoyed their playful tumbling in the wind as if I were flying among them. I entered my birds' *Umwelt*, even though imperfectly.

Whereas Uexküll wanted science to explore and map the *Umwelten* of various species, an idea that deeply inspired students of animal behavior known as ethologists, philosophers of the last century were rather pessimistic. When Thomas Nagel, in 1974, asked, "What is it like to be a bat?" he concluded that we would never know.³ We have no way of entering the subjective life of another species, he said. Nagel did not seek to know how a human would feel as a bat: he wanted to understand how a bat feels like a bat. This is indeed beyond our comprehension. The same wall between them and us was noted by the Austrian philosopher Ludwig Wittgenstein, when he famously declared, "If a lion could talk, we could not understand him." Some scholars were offended, complaining that Wittgenstein had no idea of the subtleties of animal communication, but the crux of his aphorism was that since our own experiences are so unlike a lion's, we would fail to understand the king of fauna even if he spoke our tongue. In fact, Wittgenstein's reflections extended to people in strange cultures with whom we, even if we know their language, fail to "find our feet."⁴ His point was our limited ability to enter the inner lives of others, whether they are foreign humans or different organisms.

Rather than tackle this intractable problem, I will focus on the world that animals live in, and how they navigate its complexity. Even though we can't feel what they feel, we can still try to step outside our own narrow *Umwelt* and apply our imagination to theirs. In fact, Nagel could never have written his incisive reflections had he not heard of the echo-

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I MAGIC WELLS

*What we observe is not nature in itself,
but nature exposed to our method of questioning.*
—Werner Heisenberg (1958)¹

On Becoming a Bug

Opening his eyes, Gregor Samsa woke up inside the body of an unspecified animal. Equipped with a hard exoskeleton, the “horrible vermin” hid under the sofa, crawled up and down walls and ceilings, and loved rotten food. Poor Gregor’s transformation inconvenienced and disgusted his family to the point that his death came as a relief.

Franz Kafka’s *Metamorphosis*, published in 1915, was an odd opening salvo for a less anthropocentric century. Having selected a repulsive creature for metaphorical effect, the author forced us from the very first page to imagine what it is like to be a bug. At around the same time, Jakob von Uexküll, a German biologist, drew attention to the animal point of view, calling it its *Umwelt*. To illustrate this new concept (German for the “surrounding world”), Uexküll took us on a stroll through various worlds. Each organism senses the environment in its own way, he said. The eyeless tick climbs onto a grass stem to await the smell of