Mirror, Mirror

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BACK IN 1974, an unusual report from Jane Goodall at the Gombe Stream Wildlife Research Centre in Tanzania caught the public eye. Chimpanzees had committed infanticide and were engaging in war. Not only were they acting in unanticipated ways, chimpanzees were acting like humans. Goodall's discovery bridged the divide between *Homo sapiens* and other species.

In and of itself, similarity between species is no surprise. Scientists have long experimented on animals in place of people; the resulting insights form the backbone of biomedicine and anthropology. We accept that human beings and nonhuman animals share a common ancestry. In biology and psychology, this relationship is the scientific rationale for a system of inference—the process and convention used to draw logical conclusions from observations—that allows humans to benefit from research with animal subjects. As such, it was not Goodall's discovery of species similarity per se that provoked such curiosity; it was the specific nature of the similarity.

Naked Ape, Hairy Human

The Gombe observations blurred the boundary between animal and human behavior, between nature and human nature. Previously, behaviorists thought that human and animal psychology intersected only in the realm of instinct. Homicide—as opposed to killing for access to territory or a mate—was deliberate, not instinctive. Infanticide and murder were considered exclusive to human beings and outside of nature. Goodall's findings challenged this received wisdom.

Evidence that psychology, like biology, is conserved between human and nonhuman species augurs a shake-up for science and society

Since then, what we know about ourselves and other species has changed substantially. Many studies have documented in other species the same behaviors that enrich human lives. We now recognize that species other than humans engage in an array of behaviors that bring variety and depth to life: dolphins teach cultural customs to their young, octopi demonstrate diverse personalities, and rats show a sense of humor. Once at odds with the conventions of her discipline, Goodall's interpretations today are supported by decades of research in neurobiology. They are part of a broad conceptual framework that has coalesced around the idea that psychology, like biology, is conserved among animals.

This idea isn't new. Charles Darwin placed human beings on the continuum of animal species nearly 150 years ago. Somehow that insight was lost. Nurture is being reconciled with nature, and boundaries that once separated academic disciplines are dissolving, all of which bring models of animal and human behavior to unity. Separation has given over to integration, and what seemed like a haphazard collection of observational anomalies is now taking form as a coherent, human-inclusive, trans-species theory of mind and body.

Same Difference

In addition to and underlying these changes in theory, Goodall's data contradicted inferential conventions. Chimpanzee violence suggested that ethologists could infer the origins of chimp behavior from what they understood about human violence—something hitherto dismissed as being contrary to scientific standards.

Historically, science has admitted inference from animals to humans but not the reverse. As historians Lorraine Daston of the Max Planck Institute for the History of Science in Berlin and Gregg Mitman of the University of Wisconsin–Madison, recently noted,

> Ethologists who study animal behavior, including that of primates, with close phylogenetic links to humans, have long made it a principle not to infer humanlike mental states from humanlike behavior and until [recently] many scientists in the field frowned upon any discussion of animal mental states.

Perhaps because scientists have been trained to shun such conclusions, examples of human-to-animal inference have been scarce in the scientific literature. This is one of the reasons that chimpanzee homicide, laughing mice and empathetic sheep are considered newsworthy: They represent deviations from normative models—or rather they used to. Now erstwhile behavioral isolates make up the empirical bricks in

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Jane Goodall's observations in the 1960s provided early evidence—discounted by many scientists at the time—that human and nonhuman animals shared many mental and emotional traits. In this recent photograph, Goodall duets with the orphaned chimpanzee Uruhara at the Sweetwaters Sanctuary in Kenya.

the foundations of psychobiology, and the limits on what we can infer about humans and animals have changed. Human-to-animal and animal-to-human inferences are legitimately symmetric. A deeper understanding of brain biology has strengthened this sense of equity.

Share and Share Alike

The case for inferential symmetry rests on evolutionary conservation—the levels of shared biology among animal species. At the genomic level, for example, chimpanzees and humans share 96 percent of their DNA—a figure that rises to 99 percent for genes that actually encode proteins. The genes that determine basic brain segments have changed little since vertebrates diverged from arthropods more than 500 million years ago. Not surprisingly, similar genes give rise to similar structures.

Merging human and animal models of brain and behavior raises an interesting point: Do homologous brain regions among vertebrates, or at least mammals, guarantee similar neural processes? This is a difficult question. If the brain were a computer, then it would be easier to predict that two computers with the same architecture and processor would show similar "physiology." However, matching neural blueprints are no guarantee of consistent responses. Two species may both possess a structurally similar region of the brain, yet the size of that region relative to the rest of the brain may differ. For example, two parts of the brain, the basal forebrain and extended amygdala, mediate the same functions in many species. These include the recognition of potential mates and competitors, rituals for courtship and mating, parental care (when it occurs), aggression, and territoriality.

True singularities—brain features specific to only one radiation or even species—are rare, but do exist. Certain cell types—Mauthner cells in the spinal cords of some fish and amphibians and a type of frontocortical neuron in humans—can also be unique. Novel sensory systems, such as the ability to sense bioelectric fields in some sharks, or somatosensory specializations, such as echolocation in bats, are apparently specific to the niches occupied by those species.

However, these changes in structure, function and behavior are neither random nor disconnectedly modular. Rather, they are linked by common ancestry. From an evolutionary perspective, there is no reason to favor one direction of inference over the other. Furthermore, the patterns of behavior across many species are consistent enough to warrant a shared conceptual grammar that would allow scientists to make a valid inference across species. But how does this change in theory translate to practice? In other words, if old conventions of inference have lost their monopoly, then how should scientists balance similarities with singularities? The answer comes from first principles.

Four Square

Science constantly winnows stronger hypotheses from weaker ones by testing them against current knowledge. In making such judgments, a scientist can be right by failing to reject a hypothesis that is true or by rejecting one that is false. Conversely, there are two ways of being wrong: by dismissing a valid hypothesis (what statisticians term a "type I" error) or by embracing an incorrect hypothesis (a "type II" error). With respect to inference, if humans share a trait, such as empathy, with some other animal, then the rejection of that possibility constitutes a type I error, or what primatologist Frans de Waal at Emory University refers to as *anthropodenial*. At the other end of the spectrum lies the type II error of *anthropomorphism*, the belief that humans share some trait with another animal when they actually do not.

Evolutionary theory suggests that species with a recent common ancestor are more likely to have traits in common than are distantly related species. Of course, common ancestry does not ensure identity, but as a reflexive stance, neither anthropomorphism nor anthropodenial makes sense. If morphological, physiological and genetic traits merit bidirectional inference, then there is scant reason to exclude mental states. Continuing to do so encourages systematic (and unrecognized) type I errors, thereby adding to a canon of groundless theory.

The obvious gain of a trans-species convention, in which the arrow of inference is independent of species, is consistency in theory and in practice. This dividend pays off in statistical power and subtler perception. As a bonus, such a convention would help scientists from different disciplines, such as ethology and psychology, share theories and speak a common language. But convergence to commonality calls for some additional sorting out.

Spring Cleaning

Reorganizing information that no longer conforms to past models is what science philosopher Thomas Kuhn called a paradigm shift. This is exactly what has happened with the neuroethological reinstatement of humans into the animal kingdom. Similar to other historic shifts in science, the implications are extraordinary. A trans-species standardization of nomenclature and theory suggests many parallel adjustments in long-held scientific and ethical practices. By erasing an implicit separation of human beings from other species, scientists are pressed to address conceptual inconsistencies and perhaps some uncomfortable conclusions.

Chimpanzee homicide is a clear example—society treats the same behavior in human beings as criminal and pathological. Does this mean that we should view a killer chimp as the equivalent of a felon, or must we stretch the definition of "natural" behavior for primates (including us) to include such acts? Evolutionary biologists argue that chimpanzee infanticide might be an adaptive reproductive strategy. In contrast, students of human behavior—lawyers, anthropologists and psychiatrists—regard it as abnormal. A model that accommodates both species raises questions of whether chimp violence is a disorder or an adaptive strategy, and of whether the same answer holds for human beings.

In another, less theoretical, case, the paradox of using animal models for research—that they are both categorically different from us and alike enough to study—begs resolution. The same similarities that justify the use of animals in biomedical research (an implicit anthropomorphism) clash with the dissimilarities that justify the ethics of vivisection (an implicit anthropodenial).

Trouble in Mind

Such conceptual turbulence might have remained hidden as part of the usual back-and-forth of science if the topic did not evoke such visceral responses. Old prejudices are hard to relinquish, and humans have held themselves apart from other species for centuries, if not millennia. Oxford evolutionary biologist Richard Dawkins refers to this posture as "the tyranny of the discontinuous mind." The same impetus gave rise to the medieval concept of the "great chain of being," in which humans sat above the animals but below the angels. Parasitologist Sean Nee at the University of Edinburgh attributes this self-segregation to a deep-seated fear of sameness. Regardless of its origin, bidirectional inference threatens the belief in human superiority and the self-image of those who adhere to it.

Thirty years ago, Goodall's chimpanzees reflected back something that induced powerful theoretical shifts; they may even be credited with introducing disruptive cultural change. The rapidity with which theory and data have moved since then to create a new, radically different framework portends equally significant change to come. Readjusting to a convention of bidirectional inference helps restore a sense of epistemic coherency in scientific theory and practice. And, as Kuhn reminds us, no matter what turmoil such change may engender and how daunting it may appear, the ability to embrace paradigmatic change is one of the characteristics that make science so valuable.

Bibliography

Daston, L., and G. Mitman. 2005. Introduction: The how and why of thinking with animals. In *Thinking With Animals: New Perspectives on Anthropomorphism*, ed. Daston, L., and G. Mitman. New York: Columbia University Press.

Dawkins, R. 2004. *The Ancestor's Tale*. New York: Houghton Mifflin.

Nee, S. 2005. The great chain of being. *Nature* 435:429.