of what the European Commission is trying to do, which is to try and have impact and translatable research."

The U.S. government, which has allowed some gene-edited plants on the market with no regulation, voiced its displeasure as well. "Government policies should encourage scientific innovation without creating unnecessary barriers or unjustifiably stigmatizing new technologies," U.S. Secretary of Agriculture Sonny Perdue said in a written statement that called the 2001 regulations "regressive and outdated." But the decision could benefit U.S. science if European researchers decide to seek a more welcoming home for their studies, Napier says. "It just means that we are going to export good ideas and good people to go and work in more favorable territories."

Napier is one of the scientists whose work is now in limbo. At Rothamsted, he has been growing *Camelina*, an oilseed crop, edited to lack an enzyme that converts oleic acid into linoleic acid. It's a possible step in the creation of plants that churn out omega-3 fatty acids, which have human health benefits. Created by French scientists, the plants were growing at Rothamsted because the U.K. Department for Environment, Food and Rural Affairs (DEFRA) had given field trials a green light. Now, "We're sort of sitting and waiting for DEFRA to provide advice," Napier says. (Whether the United Kingdom might become more welcoming to gene editing after Brexit remains to be seen; the U.K. government's most recent position paper makes the case for complete alignment with the European Union in agriculture.)

> ***"I find the decision depressing, a huge step backwards."***
>
> **Johnathan Napier**, Rothamsted Research

Scientists say the ruling may be impossible to enforce because it is hard to distinguish gene-edited plants from their natural counterparts. Techniques like CRISPR leave few traces in the genome of an edited plant; a small deletion may be impossible to pick out amid numerous natural changes, Jansson says. (The whole genes spliced into the genome of classical GMOs, by contrast, are easy to spot.) Jansson, for one, refuses to say what gene was deleted in his cabbage: "If I don't tell you, you cannot find out," he says.

This may not always hold true, however. *Camelina* is a hexaploid species, meaning there are six copies of each gene; having the same change in all six—something highly unlikely to occur in nature—would be a sign of gene editing, Napier says. In fact, Holland predicts the need to enforce the decision will spur research into new ways to detect gene editing.

Basic plant science may suffer, however. Detlef Weigel, director at the Max Planck Institute for Developmental Biology in Tübingen, Germany, is studying how various genetic changes can help plants adapt to climate change—and he needs to grow them outside, he says. "Again and again we have seen that there are big differences between the results we get in a greenhouse and in a field, even if we use the same earth and sprinkle the plants with rainwater." Weigel tested some edited plants in a field in Sweden this year. "Luckily we harvested the plants a few weeks ago," because the cumbersome permitting process will now make such research impractical, he says. "If we want to test a single mutant in the field, it will cost us about €500 to create that plant, and then about €250,000 to get the permit to grow it in a field."

Joyce Tait, who directs the Institute for Innovation Generation in the Life Sciences at The University of Edinburgh, says she understands scientists' frustration. "But I also feel the current gene-editing technology does enable you to make changes that are so significant that to claim 'this must be safe because it is natural' is stretching the evidence-based risk analysis," she says. She thinks Europe's regulatory system should focus on evaluating the risks of individual plants rather than the method that produced them. "If Europe sticks with the current system and the way it has operated the past 20, 30 years, I think it will become increasingly separated from the rest of the world," Tait says.

But the European ruling could also affect the rest of the world, she adds. The Cartagena Protocol on Biosafety, a supplement to the Convention on Biological Diversity, details when countries can ban certain agricultural imports for safety reasons. The European Union, a signatory to the protocol, has so far argued against including gene editing. "That could change now," Tait says, opening the way for countries around the world, including in Europe, to block imports of gene-edited crops. "It will certainly not make the trade between Europe and other parts of the world easier," Bartsch says.

Another question is whether Europe's conservative approach will reverberate in developing countries. "A lot of these countries have a much more positive inclination to these new technologies, because there are so many potential benefits," Tait says. "But there is a strong campaign by NGOs to stop this next generation of technology from taking off in agriculture." ■

HUMAN EVOLUTION

Did kindness prime our species for language?

Animal studies suggest tameness was key to language evolution

By **Michael Erard***, in Toruń, Poland, and* **Catherine Matacic**

If you want a no-fuss, no-muss pet, consider the Bengalese finch. Dubbed the society finch for its friendliness, breeders often use it to foster unrelated chicks. But put the piebald songbird next to its wild ancestor, the white-rumped munia, and you can both see and hear the differences: The aggressive munia tends to be darker and whistles a scratchy, off-kilter tune, whereas the pet finch warbles a melody so complex that even nonmusicians may wonder how this caged bird learned to sing.

All this makes the domesticated and wild birds a perfect natural experiment to help explore an upstart proposal about human evolution: that the building blocks of language are a byproduct of brain alterations that arose when natural selection favored cooperation among early humans. According to this hypothesis, skills such as learning complex calls, combining vocalizations, and simply knowing when another creature wants to communicate all came about as a consequence of pro-social traits like kindness. If so, domesticated animals, which are bred to be good-natured, might exhibit such communication skills too.

The idea is rooted in a much older one: that humans tamed themselves. This self-domestication hypothesis, which got its start with Charles Darwin, says that when early humans started to prefer cooperative friends and mates to aggressive ones, they essentially domesticated themselves (*Science*, 24 October 2014, p. 405). Along with tameness came evolutionary changes seen in other domesticated mammals—smoother brows, shorter faces, and more feminized features—thanks in part to lower levels of circulating androgens (such as testosterone) that tend to promote aggression.

Higher levels of neurohormones such as

serotonin were also part of the domestication package. Such pro-social hormones help us infer others' mental states, learn through joint attention, and even link objects and labels—all prerequisites for language, says developmental psychologist Michael Tomasello of Duke University in Durham, North Carolina, who studies social cognition.

In recent papers and at Evolang, a biannual conference on language evolution held here this spring, researchers turned to birds, foxes, and bonobos to help understand how domestication may have paved the way for language. Constantina Theofanopoulou, a neuroscientist at the University of Barcelona in Spain who convened the Evolang workshop, calls it the "most promising" working hypothesis to account for the thorny problem of language evolution, because it "puts together evidence from different levels of biological analysis: the anatomical, the brain, the endocrine system, and behavior."

In his talk at Evolang, ornithologist Kazuo Okanoya of the Riken Center for Brain Science in Wako, Japan, focused on the munia and the Bengalese finch, which people domesticated some 250 years ago. Both birds are vocal learners, a rare trait that lets them pick up calls from adult tutors—as do parrots, hummingbirds, and humans. But their songs are wildly different, as Okanoya demonstrated by whistling examples of each.

He then presented data quantifying what the audience had heard: Munia songs tend to be shorter, simpler, and full of unmelodic segments of acoustic "noise," compared with the longer, louder finch songs, which contain peeps, chirps, and segments that often repeat and recombine in improvisational ways.


The wild munia tends to be less social than the Bengalese finch, and its song is simpler.

Okanoya says the differences likely arose from domestication, in particular the finches' relatively stress-free environment. He's shown that the finches have lower fecal levels of corticosterone—a hormone that boosts aggressiveness and blunts cognitive functioning in birds—than the munia. In his talk, Okanoya reported that high corticosterone levels inhibit the growth of neurons in the birds' song-learning system, which is larger in the finches than in the munia.

Thus, Okanoya hypothesizes, selection for tameness and gregariousness by pet owners boosted the finches' capacity for complex song. And because attention-getting songs help advertise fitness to females, the males best at learning and singing would be most likely to pass their genes on to the next generation, sparking further complexity.


The society finch loves to socialize with other birds, and sings a complex, melodic song.

If early humans somehow developed their own lower-stress "domesticated" environment—perhaps as a result of easier access to food—it could have fostered more cooperation and reduced aggression, speculates evolutionary linguist Simon Kirby, writing with James Thomas, both of The University of Edinburgh, in a recent paper in *Biology & Philosophy*. As with the finch, a mellow environment may have allowed for an expanded role for learning, including in language acquisition.

Kirby and Thomas point out another analog for humans: domesticated foxes. In a famous experiment, Russian geneticist Dmitry Belyaev and colleagues selected for tameness among captured Siberian silver foxes starting in the 1950s. If a wild fox did not attack a human hand placed into its cage, it was bred. Over 50 generations, the foxes came to look like other domesticated species, with shorter faces, curly tails, and lighter coloring—traits that have since been linked to shifts in prenatal hormones.

Unlike their wild counterparts, tame foxes came to understand the importance of human pointing and gazing, Thomas and Kirby note. That ability to "mind read" is key to language. Thus, even though the foxes don't vocalize in complex ways, they show that selection only for tameness can carry communication skills in its wake.

At Evolang, other researchers zeroed in on bonobos, great apes that show some signs of self-domestication, including low levels of aggression and sensitivity to the gaze of others. According to Zanna Clay, a primatologist at Durham University in the United Kingdom, bonobos also display a building block of early language: Instead of sticking to a fixed repertoire of "inherited" calls, they can improvise.

Clay and her colleagues have assembled hundreds of recordings from 18 bonobos in the wild and in zoos, showing that individuals combine set types of calls in distinct ways for different situations. She hypothesizes that self-domestication may have helped shape this communicative flexibility.

Stronger proof may come from genetic studies. Theofanopoulou and her team recently scoured the scientific literature for genes that differ between wild and domesticated species—cats, dogs, horses, and cattle—and that also show signs of being selected in the domesticated animals. The team did the same for modern humans and what they considered our nearest wild stand-ins, Neanderthals and Denisovans.

Then, the researchers looked for genes that may have evolved in the same way in more than one wild-domesticated pair. There were more than three dozen, many linked to brain plasticity, learning, and the development of the nervous system, the team reported late last year in *PLOS ONE*. Some, such as the gene for a receptor for the neurotransmitter glutamate, are linked to processes that could shape a language-ready brain. But there's no clear path yet from these genes to their function—or to the sweeping changes linked to domestication, cautions Antonio Benítez-Burraco, a linguist at the University of Seville in Spain.

Tomasello also cautions against trying to explain human language solely from animal models. "I think humans were selected to actually collaborate," not just to get rid of aggression, he says. "[That] fundamentally cooperative motive … is a precursor to uniquely human communication." ■

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PHOTOS: (TOP TO BOTTOM) STUART HOUGH/ALAMY STOCK PHOTO; FLPA/ALAMY STOCK PHOTO

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