

The God Project

Stewart Brand helped spur the countercultural, environmental and personal computer revolutions. Now he wants to raise the dead.



Tim O'Brien

Let there be life: Genomic technologies could bring back extinct species such as (from left) the smilodon, woolly mammoth, thylacine, ivory-billed woodpecker, dodo and Pyrenean ibex.

By Patia Stephens

EXTINCTION ISN'T JUST SOMETHING that happened to the dinosaurs millions of years ago; it happens all the time. In fact, many scientists believe that we are in the midst of a mass extinction right now. If that's the case, it would be the sixth such event since the beginning of the fossil record around 540 million years ago. Only, unlike previous mass extinctions, which were caused by things like asteroid impacts and supernovas, this one appears to be largely—if not entirely—the fault of mankind.

The International Union for Conservation of Nature (IUCN) maintains a "red list" of species known to have died out in the past 500 years. On it are 709 animals, including 325 mammals, fish,

amphibians, reptiles and birds, and 90 plants; an additional 61 species are listed as extinct in the wild. Where they can be deduced, the causes are also listed and include things like environmental degradation, introduction of invasive species, habitat loss and overexploitation.

It's difficult to get a bead on the magnitude of the problem, though, since we don't know the denominator in the equation. Around 1.5 million species have been identified, but there could be 5 million, 10 million or 30 million. Some estimates even go as high as 100 million. Scientists calculate that at a minimum, the current rate of extinction is an order of magnitude higher than the naturally occurring rate.

Since the beginning of the 20th century alone, 100 species of mammals, amphibians and birds have disappeared forever. Or so we thought. Then, for a moment in 2009, it was 99.

In 2000, the last remaining Pyrenean ibex, a type of wild mountain goat also known as a bucardo, was found dead, its skull crushed, in a protected park in Northern Spain. The species had already been hunted to extinction in the wild years before. But its DNA lived on, in a preserved tissue sample.

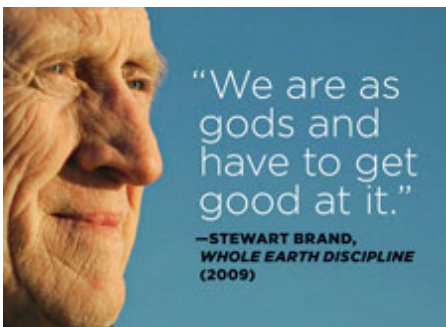


Photo: Robert Stone

Beginning in 2003, a team of Spanish and French scientists attempted to insert cell nuclei from the final bucardo into eggs from a living goat that had been emptied of their own genetic material. The chimeric embryo would then be implanted in the womb of a surrogate mother, an ibex-goat hybrid. The technique, called somatic cell nuclear transfer (SCNT), is more colloquially known as cloning.

After 57 implantations resulting in seven pregnancies, there was a single live birth, in 2009. The baby bucardo died 10 minutes later, succumbing to a lung defect common in clones. But for a brief moment, the Pyrenean ibex was no longer extinct.

News of the breakthrough spread, eventually reaching a harbor in Sausalito where Stewart Brand lives with his wife of 30 years, Ryan Phelan, aboard a 64-foot tugboat called the *Mirene*.

Brand, '60, has an uncanny knack for being at the center of things before anyone else gets there. His exploits with Ken Kesey, Gr. '59, and the Merry Pranksters were chronicled in Tom Wolfe's 1968 book *The Electric Kool-Aid Acid Test*. That same year he assisted Stanford engineer Douglas Englebart with the "mother of all demos," introducing personal computing as we know it. And early in the dial-up-modem days of 1984, he created a prototypical online community called the WELL (Whole Earth 'Lectronic Link).

At a 2011 seminar in San Francisco addressing the question "Is Mass Extinction of Life on Earth Inevitable?"—part of a series organized by nonprofit Long Now Foundation, which he co-founded in 1995—Brand wondered aloud about the potential of emerging genomic technologies to resurrect extinct species. "I suppose we could get passenger pigeons back," he mused. "I hadn't thought of that before."

Brand conferred with experts such as biologist E.O. Wilson and geneticist George Church of Harvard about the feasibility of de-extinction and realized it wasn't a matter of *whether* but *when*. "If some entity did not take on de-extinction and try to move it forward in a responsible way," he worried, "it would stumble into the world through different avenues that might not care about conservation." So in 2012 he and Phelan launched Revive and Restore under the auspices of Long Now, which serves as an umbrella organization for ambitious projects that aim to promote responsible decision making for the future.

"We're trying to make sure that de-extinction, as it becomes a scientific discipline, moves forward in a responsible way," he says.

BORN IN 1938, the youngest of four siblings, Brand spent his childhood roaming the woods near Rockford, Ill., a manufacturing town nicknamed "Forest City." His father, an MIT-trained engineer, ran an advertising agency and was a ham-radio hobbyist. His mother, a graduate of Vassar, was a homemaker and space enthusiast.

As a high school senior at Phillips Exeter Academy, he planned to go to college in Idaho and become a firefighter, when a teacher steered him toward Stanford. His older brother Michael, '54, had attended and Brand had a Sloan Scholarship (though his father was too proud to let it pay his tuition), so at the last minute he opted for the Farm.

Majoring in biology, he studied tarantulas on Jasper Ridge with biologist Paul Ehrlich as an adviser. He also took plenty of humanities courses including magazine journalism, German language, comparative religion and Christian mysticism. "I wanted to do the subjective-oriented courses, but I also wanted the objectivity," he says. "I was influenced by everybody from John Steinbeck [23] to Aldous Huxley."

One memorable moment on campus came in the spring of 1957 when a 5.3 magnitude temblor rocked the Peninsula. "I was lying outside looking up at the blue sky, and here came the earthquake. It was wonderful."

Years later, Brand was again looking up at the sky, this time from a North Beach rooftop while tripping on LSD, when he wondered, "Why haven't we seen a photograph of the whole Earth yet?" He distributed buttons bearing the question that became popular from the Haight to the headquarters of NASA, which released the "Earthrise" photo taken by an Apollo 8 astronaut in 1968.

Brand put the now-iconic image on the cover of the first edition of his *Whole Earth Catalog*. Published regularly between 1968 and 1972, it was a *Farmers' Almanac* cum Sears Roebuck catalog for the countercultural set. In his 2005 Commencement speech at Stanford, Steve Jobs called it "one of the bibles" of his generation. "It was sort of like Google in paperback form," the Apple co-founder said.

An impetus akin to the one behind the *Whole Earth Catalog* led him in 2001 to embark on a massive project to find and document all life on Earth within 25 years. Speaking to a reporter for the *Guardian*, Brand said he was attempting to raise \$3 billion for the initiative, which he was calling the All Species Inventory.

The money ran out and in 2003 the project was shelved. But like the bucardo, a trace of its DNA remained, to be resurrected nearly a decade later as Revive and Restore.



XERCES BLUE BUTTERFLY
Glaucopsyche xerces
EXTINCT SINCE 1941

Once endemic to San Francisco's Sunset District, the Xerces blue is thought to be the first American butterfly species lost due to urban development. Its L.A. cousin, the Palos Verdes blue, is being bred in labs and could serve as a suitable surrogate.



AUROCH
Bos primigenius
EXTINCT SINCE 1672

IF YOU WANT TO BRING BACK an extinct species, the first thing you need is its complete DNA code. For the SCNT method, this means obtaining live or cryogenically preserved cells, such as those in the San Diego Frozen Zoo, a high-tech ark in which tissue samples from endangered species are being collected and stored. Scientists in Australia are using the technique to try to resurrect a strange frog that gives birth through its mouth. The gastric-brooding frog went extinct in 1983 but, using cells stored in a conventional freezer, the researchers successfully cloned several tadpoles. None survived to froghood, but the advance still garnered the technique a spot on *Time's* 25 Best Inventions of 2013 list.

Cloning won't work with taxidermic museum specimens or fossilized remains, though, because the genetic material is too fragmented and contaminated. But other techniques might.

One strategy being explored is genetic engineering, which involves isolating snippets of DNA and using computer programs to compare the sequences to closely related species and stitch the pieces together correctly. That template can then be used to assemble the extinct genome and, as with SCNT, combine the genetic material with an egg from living species to be borne (or hatched) by a

To modern cattle what Neanderthals are to man, aurochs ranged across Europe, Asia and North Africa from the late Pliocene to the Holocene. A complete DNA sequence, from an exceptionally well-preserved sample of bone, was published in 2010.

surrogate.

Beth Shapiro, associate professor in ecology and evolutionary biology at UC-Santa Cruz, is sequencing the DNA of passenger pigeons, assisted by a young scientist, Ben Novak, who wants to resurrect the once prolific North American bird, the last of which died in 1914 at the Cincinnati Zoo. In Australia, work is in progress on sequencing the Tasmanian tiger's DNA from an ethanol-preserved specimen of the marsupial, which went extinct in the 1930s. And in England, researchers are attempting to piece together the DNA of the dodo, a flightless bird that disappeared in 1680, from museum specimens.

While promising, genetic engineering remains in its infancy. Challenges include identifying sequences that encode key traits and finding the right place in the host genome to splice the assembled DNA. And, as with cloning, there can be problems with cross-species gestation.

Another approach that scientists are trying is called breeding back—essentially selective breeding, which humans have employed for thousands of years to select for desired traits in domestic animals. But rather than selecting for more meat in cattle or shorter tails in dogs, they're targeting traits of long-gone species, such as the European aurochs, the wild cattle immortalized in the cave paintings of Lascaux. It's a slow process, but in addition to the auroch effort in Europe, breeding back is being employed with some success to resurrect the quagga (a type of zebra) in South Africa and the Galapagos tortoise in South America.

BRAND'S MISSION VIA REVIVE AND RESTORE is to bring all these disparate research groups, as well as other stakeholders, together as a community to share knowledge and shape norms as the science matures. Last spring, he spoke at a campus conference on "De-Extinction: Ethics, Law and Politics" hosted by the Law School and organized by Hank Greely, a professor of law and, by courtesy, of genetics.

The Stanford conference was the third significant gathering on de-extinction, after two 2012 meetings at Harvard University and National Geographic Society headquarters in Washington, D.C., co-organized by Revive and Restore. Introducing Brand's lunchtime talk, Greely, '74, remarked, "I think Stewart Brand is the human equivalent of charismatic megafauna."

Indeed, Brand is tall and lanky with an impish smile and quiet charisma. At 75, he is fit and perpetually dressed for the outdoors, down to the knife and toolkit he wears on his belt. He spoke wistfully about enormous flocks of passenger pigeons that once darkened the skies of the Eastern United States for days. "Humans have made a huge hole in nature in the last 10,000 years," he said. "We have the ability now, and maybe the moral obligation, to repair some of the



ATLANTIC GRAY WHALE
Eschrichtius robustus
EXTINCT SINCE EARLY 1700s

A preference for shallow waters close to shore made the Atlantic Gray easy prey for whalers who wiped out the population off the Eastern coast of the United States. Bringing it back could be a boon for ecotourism.

damage."

To that end, Brand views technology as an important tool. "Because I'm an ecologist by training, a futurist by profession, and a hacker (lazy engineer) at heart," he has written, "my bent is scientific rigor, geoeconomic perspective, and an engineer's bias, which sees everything in terms of solvable design problems."



PASSENGER PIGEON
Ectopistes migratorius
EXTINCT SINCE 1914

Pigeons are known to breed well in captivity and have been successfully reared using puppets. Because they feed on seeds, the return of the passenger pigeon to the skies could benefit forest biodiversity.

Not everyone agrees, but Brand is no stranger to controversy. In his 2009 book *Whole Earth Discipline: An Ecopragmatist Manifesto* he extolled urban density, nuclear power, genetically modified crops and geoengineering, riling many rank-and-file environmentalists. (Brand himself had previously spoken out vociferously against nuclear power and GMOs, but says he had an educated change of mind. His opinions, he explains, are "strongly stated and loosely held.")

For his part, Greely says one motivation for convening the Stanford conference was to examine his own ambivalence about de-extinction. On one hand, the bioethicist, who tends to be the sober voice urging caution and restraint, confessed in an April 2013 *National Geographic* cover story, "What intrigues me is just that it's really cool. A saber-toothed cat? It would be neat to see one of those." But on the other hand, he noted, "In some ways, the most powerful argument for the Endangered Species Act is that extinction is forever. Well, what if it isn't?"

He also acknowledged the potential for negative environmental impacts, like cities buried in an inch of passenger pigeon poop. "You'd hate to let loose the next kudzu—an invasive species that takes over and ruins the environment."

Chuck Bonham, director of the California Department of Fish and Wildlife, was a nervous participant in the panel discussion on

environmental law. He spoke about the California grizzly bear, which now exists only on the state flag, and the divisiveness surrounding wolf reintroduction. "I have mixed feelings about de-extinction," he said, emphasizing that he was speaking personally, not on behalf of his agency. "How do we regulate it? This scares us because we don't know what to do."

Panelist Matthew Liebman, senior attorney with the Animal Legal Defense Fund, argued that it's hard to justify de-extinction from an animal welfare perspective. He raised concerns about the potential cruelty of subjecting animals to egg harvesting, surrogate pregnancies, lives spent in captivity and suffering when things go wrong. "Some of the animals that have been cloned certainly live every moment in agony," he said, citing the ill-fated bucardo. "The entirety of her existence outside of the womb was in intense respiratory distress."

Other speakers argued that creating one life does not balance the scales for the destruction of another. "What are we obligated to do if it doesn't matter who we owe?" asked Hilary Bok, a philosophy professor and director of the bioethics program at Johns Hopkins University. "We do not undo the sin by having the hubris to bring them back."

Elizabeth Hadly, a senior fellow in the Stanford Woods Institute for the Environment, didn't attend the conference. She sees de-extinction as a distraction from conservation efforts: "I think it is a waste of our intellectual and financial resources."

One of 520 global scientists who recently signed a consensus statement on climate change, Hadly points out that up to 75 percent of current species on Earth may go extinct within coming centuries. "We're not even doing a good job taking care of the species we have on the planet now," she says. "Why would we bring back a species that is threatened and doomed to go extinct again? We're going to bring back a woolly mammoth? Frankly, I'd rather keep the elephants alive."

SPARKING THESE DEBATES is of course the point of such gatherings, which Revive and Restore continues to convene to keep the conversation about de-extinction going. On balance, though, Brand believes the positives will outweigh the negatives.

Current technologies are unlikely to create perfect genetic replicas of extinct species, let alone fully restore them to their former glory. The creatures, born initially in labs, will emerge into a vastly different world from the one their ancestors knew. They'll have different habitats and be reared by animals with different behaviors, epigenetic expression and microbiomes.

Even Beth Shapiro asks, "Is it enough to make the band-tailed pigeon look like the passenger pigeon and have the same colors as the passenger pigeon, or does it also have to have the same behaviors and range as the passenger pigeon?"

But getting even partway there could prove beneficial. Researchers would gain new insights from studying similarities and differences between extinct species and their living kin. And the tools used, genetic engineering for example, could help augment diversity in "zombie species," like the Nile rhino, that are all but doomed to extinction because there are so few individuals left.

Reintroducing a revived species to its former domain could aid habitat restoration. For example, the dung of newly created passenger pigeons could fertilize the forests of the Eastern United States. And woolly mammoths and other native fauna could help restore the grassy steppes of the Siberian tundra.

"Add them all up, the result won't be perfect," acknowledged Brand, speaking at a 2013 TED conference. "But it should be perfect enough, because nature doesn't do perfect, either."

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