Meet the Scientists Bringing Extinct Species Back From the Dead

Illustration: Sagmeister & Walsh

By
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The pigeons are outwardly unremarkable. Thirteen birds, ages two weeks to three months, occupy a coop at an animal research facility west of Melbourne, Australia. They're descendants of the common rock pigeon, recognizable denizens of city squares and park benches—with one small but crucial distinction. These are the first pigeons in history with reproductive systems that contain the Cas9 gene, an essential component of the Crispr gene-editing tool. The squabs of this flock will be born with the Cas9 gene in every one of their cells, allowing scientists to edit their offspring with DNA from the extinct passenger pigeon. Those birds, if everything goes to plan, will be the first live animals edited with traits from a species that no longer exists. The flock was created by Ben Novak, an American scientist who has spent the past six years working obsessively on a process known as de-extinction. His goal: to bring back a bird that disappeared from the face of the Earth in 1914.

Over the past six years, new gene-editing technology has given us previously unimaginable control over genetics. The Crispr-Cas9 system consists of two main parts: an RNA guide, which scientists program to target specific locations on a genome, and the Cas9 protein, which acts as molecular scissors. The cuts trigger repairs, allowing scientists to edit DNA in the process. Think of Crispr as a cut-and-paste tool that can add or delete genetic information. Crispr can also edit the DNA of sperm, eggs and embryos—implementing changes that will be passed down to future generations. Proponents say it offers unprecedented power to direct the evolution of species.

In January 2013 scientists published papers demonstrating that, for the first time, they had successfully edited human and animal cells using Crispr. The news sparked fears of so-called designer babies edited for traits like intelligence and athleticism, something scientists stay is still far off because of the complexity of those traits. But editing of embryos for research is already under way. In the past 18 months, researchers in the U.S. and China successfully edited disease-causing mutations in viable human embryos not intended for implant or birth.

The technology is widely used in animals. Crispr has produced disease-resistant chickens and hornless dairy cattle. Scientists around the world routinely edit the genes in mice for research, adding mutations for human diseases such as autism and Alzheimer's in a search of possible cures. Crispr-edited pigs contain kidneys that scientists hope to test as transplants in humans.

Crispr has been discussed as a de-extinction tool since its earliest days. In March 2013 the conservation group Revive & Restore co-organized the first TedXDeExtinction conference in Washington, D.C. Revive & Restore was co-founded by Stewart Brand, the creator of the counterculture Whole Earth Catalog and a vocal advocate for a passenger pigeon revival.

At the conference, George Church, a Crispr pioneer and geneticist at Harvard Medical School, laid out a scientific roadmap for reviving a species. Church focused not on the passenger pigeon but on his own pet project, the woolly mammoth. Scientists, Church explained, had partially sequenced the mammoth's genome using DNA extracted from ancient bones and other remains. Armed with that information, they could use Crispr to edit DNA from the Asian elephant, the mammoth's closest living relative. Through genetic cutting and pasting, physical and behavioral traits of the mammoth—its namesake coat and ability to withstand subzero temperatures—could be added to living elephant cells.

The idea that woolly mammoths might once again roam the Earth made headlines around the world. But in his talk, titled "Hybridizing With Extinct Species," Church said that the intended result of his de-extinction experiment was not a genetic facsimile of the mammoth. With enough mammoth DNA, Church explained, a Crispr-edited Asian elephant would become something else entirely: a modern hybrid that looked and behaved like a mammoth but shared DNA with a living species.

For many in the audience that day, an idea straight out of science fiction suddenly seemed plausible. "Crispr put de-extinction on the plate," says Novak, who spoke at the TedXDeExtinction conference and directs the passenger pigeon project for Revive & Restore.

The passenger pigeon has a cultlike following—a global network of “pigeoners” that includes scientists, conservationists, ornithologists, pigeon breeders, poultry geneticists and avid birders eager to see the species revived. Even among these obsessives, Novak’s passion stands out. Of the 1,500 stuffed passenger pigeons in museums and private collections, he has personally viewed 497.

He understands that his obsession is difficult for most people to understand. He has a hard time explaining it himself. Novak grew up in a town of 200 people in North Dakota. Long before he could read, he was fascinated by the idea of extinction, digging unsuccessfully for fossils in his backyard. “I was an odd child,” he says.

There is no plan to bring back the pterodactyl. De-extinction does not mean ‘Jurassic Park.’ Illustration: Sagmeister & Walsh

In eighth grade, Novak was working on a science-fair project on the dodo bird when he discovered that the species was essentially “a giant extinct pigeon.” Nothing prepared him for the rush he felt when, at age 14, he came across photos of a passenger pigeon while flipping through a National Audubon Society book.

“I thought it was a gorgeous bird,” Novak says.

Male passenger pigeons were particularly colorful, with red breasts, feet and legs and iridescent pink patches that glistened on the sides of their throats. The birds traveled in flocks that could number three billion, and were known for their grace and speed, flying at up to 60 miles per hour. Novak read histories that described passenger pigeon flocks so large, they darkened the skies for days as they passed overhead. These massive flocks played an important ecological role, breaking branches to allow sunlight to rejuvenate forests and enriching the soil with their excrement. The birds were prized for their meat; hunters could see the flocks approaching from miles away. The population went into steep decline in the late 1800s and never recovered.

The last known passenger pigeon—a bird named Martha—died in captivity at a Cincinnati zoo in 1914. Her demise sparked the passing of modern conservation laws to protect other endangered species in the U.S. Shortly after her death, Martha was frozen and shipped to the Smithsonian Institution in Washington, D.C., to be stuffed. She's no longer on display, but Novak has, of course, seen her. "Martha is in bad shape," he says. Written history and degraded taxidermy intensified Novak's desire to revive the species. "No one can tell me what a passenger pigeon was like in real life," he says. "I feel robbed of history."

The first step was to sequence the passenger pigeon genome. The project was led by Beth Shapiro, a professor of ecology and evolutionary biology at the University of California, Santa Cruz and the author of the book "How to Clone a Mammoth." Shapiro's lab studies the DNA of extinct animals, extracting fragments from bones and other remains, some dating back hundreds of thousands of years. Novak joined the lab in 2013 to work on the passenger pigeon project; Revive & Restore funded his work.

Sequencing an extinct species' genome is no easy task. When an organism dies, the DNA in its cells begins to degrade, leaving scientists with what Shapiro describes as "a soup of trillions of tiny fragments" that require reassembly. For the passenger pigeon project, Shapiro and her team took tissue samples from the toe pads of stuffed birds in museum collections. DNA in the dead tissue left them with tantalizing clues but an incomplete picture. To fill in the gaps, they sequenced the genome of the band-tailed pigeon, the passenger pigeon's closest living relative.

By comparing the genomes of the two birds, researchers began to understand which traits distinguished the passenger pigeon. In a paper published last year in "Science," they reported finding 32 genes that made the species unique. Some of these allowed the birds to withstand stress and disease, essential traits for a species that lived in large flocks. They found no genes that might have led to extinction. "Passenger pigeons went extinct because people hunted them to death," Shapiro says.

In a Harvard lab, Asian elephant cells are being edited with DNA from the extinct woolly mammoth. Illustration: Sagmeister & Walsh

In 2014, Shapiro taught a graduate class on de-extinction and asked each student to make a case for bringing one animal back from the dead. Extinct flightless birds—the moa of New Zealand and the dodo—were favorites, along with the Yangtze River dolphin. Some students cited an animal's ecological importance or value to tourism. Others mentioned the role humans played in the extinction of a species—a cornerstone of Stewart Brand's argument for reviving the passenger pigeon.

According to Shapiro, none of these arguments justifies de-extinction. "What's the point of bringing something back if we don't know why it went extinct?" she asks. “Or if we do know why it went extinct but haven’t fixed the problem?”

The dodo, she says, exemplifies the latter issue. The flightless bird, native to the Indian Ocean island of Mauritius, nested on the ground and laid only one egg at a time. Settlers who arrived in 1638 brought cats, rats and pigs that devoured dodo eggs. “There is no point in bringing the dodo back,” Shapiro says. “Their eggs will be eaten the same way that made them go extinct the first time.”

Revived passenger pigeons could also face re-extinction. The species thrived in the years before European settlement of North America, when vast forests supported billions of birds. Those forests have since been replaced by cities and farmland. “The habitat the passenger pigeons need to survive is also extinct,” Shapiro says.

Her interest in the bird was rooted in conservation rather than de-extinction. Understanding the exact cause of species’ extinction can help scientists protect living animals and ecosystems. Shapiro argues that passenger pigeon genes related to immunity could help today’s endangered birds survive. “I wanted to study the passenger pigeon,” Shapiro says. “Ben wanted to bring the passenger pigeon back to life.”

But what does it mean to bring an extinct species back? Andre E.R. Soares, a scientist who helped sequence the passenger pigeon genome, says most people will accept a lookalike as proof of de-extinction. “If it looks like a passenger pigeon and flies like a passenger pigeon, if it has the same shape and color, they will consider it a passenger pigeon,” Soares says.

Shapiro says that’s not enough. Eventually, she says, gene-editing tools may be able to create a genetic copy of an extinct species, “but that doesn’t mean you are going to end up with an animal that behaves like a passenger pigeon or a woolly mammoth.” We can understand the nature of an extinct species through its genome, but nurture is another matter. With no living woolly mammoths or passenger pigeons to model social behavior, who will teach these genetic replicas how to behave like their kind?

“We are going to need a new biology and new names for all this,” Soares says.

Agriculture is turning to automation as it grapples with growing demand and a shrinking labor force. In this episode, we meet the robots making farms more efficient.

Church concedes that there are obstacles to de-extinction, not the least of which is public apprehension. But the history of science, he says, is filled with ideas that start out sounding far-fetched, raise complex ethical issues and over time move toward social acceptance. “The more unknowns there are, the more intense the disagreement,” he says. He points to in vitro fertilization, now a routine reproductive technology that has led to the birth of millions of children. When IVF was first proposed, people worried about the ethics, repercussions and possible risks. “As soon as Louise Brown was born in 1978 and completely normal, the disagreement disappeared,” Church says.

In almost every country, the process of de-extinction requires approval from governments, academic committees and the public along the way. To inject the Cas9 gene into his birds, Novak needed permission from the Office of the Gene Technology Regulator in Australia as well as ethics and animal welfare committees. He’ll need another round of approvals to breed and edit the next generation of his pigeons.

In the meantime, Novak is steadily building the flock. In May he injected 19 eggs with the Cas9 gene, but only two pigeons survived hatching. In August, 11 squabs survived from 46 eggs. Novak and a small team of scientists plan to repeat the process until they have 22 pairs of birds for breeding. They’re considering which passenger pigeon traits to add first, combing through the sequencing data for the genes associated with the extinct bird’s distinctive coloring and preference for life in large flocks. After he determines how passenger pigeon DNA manifests in the rock pigeons, Novak hopes to edit the band-tailed pigeon, the passenger pigeon’s closest living relative, with as many of the extinct bird’s defining traits as possible. Eventually, he says, he’ll have a hybrid creature that looks and acts like a passenger pigeon (albeit with no parental training) but still contains band-tailed pigeon DNA. These new-old birds will need a name, which their human creator has already chosen: Patagioenas neoectopistes, or “new wandering pigeon of America.”