Genetic patterns of world's farmed, domesticated foxes revealed via historical deep-dive

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Credit: Anna Kukekova, University of Illinois Urbana-Champaign

Domesticated animals play a prominent role in our society, with two-thirds of American families enjoying the companionship of pets and

many others relying on animal products for their nutritional needs. But the process of domestication remains a bit of a mystery. Convincing wild animals they are safe enough to coexist and mate in enclosures and in close proximity to humans and other animals is no small feat. What does it take behaviorally and genetically for that to happen?

For the most part, the animals we've domesticated have been docile for so long that there's no easy way to go back and study the transition from wild to tame. A notable exception is the domestication of red foxes—raised in captivity for their fur—starting in 1896 on Canada's Prince Edward Island. A team from the University of Illinois Urbana-Champaign has traced the process from its beginnings on the island to captive fox populations around the world, including some still in operation today.

The work is published in the *Journal of Heredity*.

"We have the historical documents, we have genetic information about wild fox populations all over the world, and we obtained samples from foxes bred in North America and Eurasia. So we can really dig into the question of how foxes were domesticated and how their genetics were shaped by geography and time," said lead study author Halie Rando, an assistant professor at Smith College who completed her doctoral research in the Illinois Informatics Institute, now in the School of Information Sciences, at Illinois.

Rando, along with Illinois animal sciences professor Anna Kukekova and their collaborators, analyzed new and previously published mitochondrial DNA data from wild fox populations and from 10 captive populations in North America and Eurasia, including the site of the famous Russian fox domestication experiment. They then cross-referenced historical records related to the intercontinental trade of foxes, changing fur demand and farm sizes, and breeding practices. Together, the data allowed them to

determine the geographical origins of farmed foxes worldwide and understand the role of genetic diversity in the domestication process.

"When we do population genetics research, we're able to uncover history forensically," Rando said. "Looking at signatures that are in present populations, we can make inferences about the past."

Early fox farmers were motivated by the demand for the silver variant of red foxes. Trying to trap rare silver foxes from the wild was unreliable and difficult, but breeding them in captivity had its own challenges.

"The foxes were very hard to breed on the farms because they would get really stressed out and die or kill their offspring. It took a long time for them to figure out how to set up the breeding enclosures to reduce stress. Along the way, they were selecting for individuals that were better suited to the farm environment," Rando said. "They also managed to select for the silver fur color. Even without knowing any genetics, they figured out how to crack the code."

After that, the industry boomed, with Canadian foxes being exported across the world. The genetic analysis showed that every captive population the researchers surveyed—even those in Eurasia—originated from wild North American foxes. In fact, there were no traces of genetic markers from Eurasian wild fox populations, suggesting any attempts at domesticating local populations were abandoned or overtaken by North American genetics.

"This study helps to answer questions researchers have asked for years about the geographic origin and genetic background of these fox populations," Kukekova said. "Furthermore, some farm foxes may have mixed with native foxes through release events over the years in different locations. Occasionally, unexpected gene signatures show up in native populations, so our study may help to explain where they're

coming from."

World War II interrupted demand, and the industry never recovered in North America. In the USSR, however, fox farms quickly rebounded, aided by the government-supported fur industry.

Overall, the genetic pattern reflects the more stable history of breeding in Eurasia. Although all the farmed foxes in the study were found to originate from North American wild foxes, populations in Eurasia were more genetically diverse, with greater representation from Alaskan and western U.S. genotypes in addition to common genotypes from Eastern Canada.

"Some gene signatures were very rare and found only in certain Eurasian farm populations," Rando said. "The presence of these rare signatures, along with more diversity overall in Europe, could be due to more stable population sizes there after World War II, whereas those rare types may have been lost when North American farms collapsed."

The study also sheds light on the famous Russian Farm Fox experiment, started in 1959 at the Institute of Cytology and Genetics (ICG) in Novosibirsk. The study originated with the selection of farm-bred foxes that showed the least avoidant behaviors around humans. Through successive generations, scientists selectively bred foxes with tame behaviors, eventually resulting in foxes as friendly as the family dog.

The current study sampled that population and analyzed it along with the others, finding no unique genetic origins for the Russian foxes. To Rando, this suggests that farm-bred foxes may have the same underlying capacity to develop friendly behaviors.

"I'd say we pretty conclusively demonstrated that the foxes in Novosibirsk are not meaningfully different from other farm-bred foxes

in terms of their genetic origins. We also found that the populations in Novosibirsk were among the most genetically diverse captive populations, likely due to their meticulous pedigree records and carefully planned breeding," she said.

Kukekova added, "It's informative to know that this one successful endeavor in Prince Edward Island really had a huge effect on modern populations that persists to this day. The model can help us study domestication broadly and find gene networks leading to tame behavior, which is something that humans have been interested in for a very long time."

More information: Halie M Rando et al, Missing history of a modern domesticate: Historical demographics and genetic diversity in farm-bred red fox populations, *Journal of Heredity* (2024). DOI: 10.1093/jhered/esae022

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