

Where did the chicken cross the road?

Published 16 November 2020, with Olivier Hanotte.

Olivier Hanotte is a principal scientist with the International Livestock Research Institute, based in Ethiopia, and a professor of genetics at the University of Nottingham in England. He's an expert on working out the distant evolutionary history of animals by looking at their DNA.

The central idea is that the more different two samples of DNA are, the more time has passed since they shared a single common ancestor. In some cases, including humans, the DNA can even be extracted from ancient bones, which gives you a firm archaeological date.

But not, alas, chickens.

Olivier Hanotte: For chicken it is actually very difficult to actually find old bones of chicken and to examine those, because the bones of the bird are very fragile and often are not being recovered properly in archaeological remains. Another challenge is that chickens belong to a family of birds which includes a lot of other species, including pheasants. Sometimes chicken bones, unless they are very well preserved, are simply very hard to identify. So, for the geneticist who is interested in the domestication of the chicken, chicken bones, the study of DNA, could in theory provide information — but the difficulty is to get the sample. It's not easy. So we have to rely on what we have today.

Jeremy: What we have today is modern DNA, and what's true of ancient DNA is also true of modern DNA. The more similar, the more closely related. Also, the greatest diversity among breeds will be found close to where the species was first domesticated, because that is where it has been evolving for the longest time. On that basis, two places were competing to be the ancestral home of the chicken: The Indian sub-continent and southeast Asia.

Hanotte was part of a huge group of colleagues who looked closely at modern DNA from hundreds of chicken breeds and wild junglefowl to try and decide between the two competing locations for chicken domestication.

Olivier Hanotte: The latest story now, coming out from a recent publication published in 2020, it seems that the first region of domestication was actually in Southeast Asia. They were able to show that all the domestic chickens had their ancestry from essentially a subspecies of wild chicken which is today living in Southeast Asia.

Jeremy: Can you be more precise. Southeast Asia is huge.

Olivier Hanotte: You're right. You can't pinpoint exactly the one point, but it is an area ... we're talking about western China, Burma, Thailand, somewhere there. And then from there, the chicken dispersed to where we find them today. But the story is not as simple as that, of course, because this is just the beginning. But then what happened? Chickens travel a lot, like other livestock, they travel with humans. And then when they travel they meet other wild species of chickens.

Jeremy: That was going to be my question. As they move around there are still junglefowl there, and presumably a junglefowl rooster might get access to a domesticated chicken and maybe they would have eggs and chicks together.

Olivier Hanotte: Exactly, and this did happen. The results so far indicate that when the chicken from southeast Asia arrived on the Indian continent, they coupled with the wild chickens from the Indian sub-continent. So in other words, the chickens from Europe, they do have this ancestry from Southeast Asia, but they also carry with them an ancestry from the Indian sub-continent.

Jeremy: So, settled for now.

Chickens crossed the road to domestication about six or seven thousand years ago in western China, Burma, Thailand. But they picked up a lot of genetic diversity from birds in India and elsewhere before spreading further afield. And there's one abiding mystery in that spread.

There are chickens on the west coast of South America, and some people have said that they travelled east, from Asia, rather than westward, three quarters of the way around the world, *via* Europe and Columbus. The problem is that the archaeological dates for chicken bones found in Chile just aren't that conclusive. Does the DNA throw any light on that?

Olivier Hanotte: I have been involved in a study where we had to elucidate the genetic control of the blue eggs in chicken. The araucana is a South American bird, from the Araucana people, and it is laying blue eggs. And the interesting thing is that there are other birds, other chickens, which are laying green eggs, but in fact green is simply the superposition of blue against brown. So they are laying green eggs and they are found in China. So if we could show that the genetic control of this phenotype is identical between the birds of Asia and the birds of America, maybe we have here an argument that indeed they could have been introduced, the South American ones, from Asia.

So we investigated that, and while we did identify the genetic control, and we did identify that it is the same gene which is most likely involved in both cases, it is not the same mutation. So, bad luck. That didn't solve the problem either.

You know, the Polynesian people are actually the ones who dispersed the chicken all across the Polynesian islands. It is not at all impossible that indeed first they visited the coastal area of South America, and there they brought chicken with them before the Europeans settled down in that part of the country. So, it is perfectly possible, but we do not have yet indisputable evidence for it.

Jeremy: One day, we may know for sure.

Anyway, leaving chickens there in Chile, let's turn to sheep. They were domesticated in the Fertile Crescent in the Near East, the same area as wheat, barley, chickpeas and so on. So what's the story there?

Olivier Hanotte: The sheep story is ... If you look at the distribution of the wild sheep, you find them, not as widely distributed as the chicken, but nevertheless, in the Middle East at least, quite a wide distribution. To pinpoint exactly the domestication area is difficult, and possibly there wasn't really a single one. It could have been happening in quite a broad geographical area in the Zagros mountain area. But of course what is interesting about sheep, is that if you look today, morphologically you do find a huge diversity among the sheep. Most likely the first domestic sheep were quite different in this respect. They were what we call hair sheep, and wool sheep were probably developed later. And then even later, likely, you have another type of sheep that is what we call fat-tailed sheep.

Jeremy: I'll come back to fat-tailed sheep, but wool, for the record, keeps growing, unlike hair, which tends to stop at a characteristic

length. Wool fibres are also slightly crimped, which makes them easier to spin into yarn and also helps them trap an insulating layer of air.

The first sheep — about 12,000 years ago — were hair sheep, raised mostly for meat and milk. People began to select woolly sheep about 8000 years ago, using the wool to weave clothing and rugs. And fat-tailed sheep show up around 5000 years ago, still around the Fertile Crescent. They have large deposits of fat around the tail and hind-quarters, rather like a camel's hump. The tail fat is apparently absolutely delicious, which may be why these breeds were first selected, although it also probably helps them to survive harsh desert conditions.

Now, of course, sheep are found all over the world, including some very cold spots, like the Tibetan Highlands. Again, that's partly thanks to their genetic diversity, and partly thanks to other sheep they encountered along the way.

Olivier Hanotte: It is actually not impossible that they managed to occupy these areas, like the Tibetan highlands, by crossing with some other species of sheep. As in chicken, there are several species of sheep, and the crossing of these domestic sheep of the Near East with some local or wild species of sheep may have brought diversity, which at the end made them more adaptable.

Jeremy: And it is crossing that underpins our final example of livestock domestication: cattle.

Unlike chicken, where there was probably a single domestication event, and sheep, where there may have been many but they all took place in roughly the same area, cattle were different.

Olivier Hanotte: In the case of cattle, we do have at least two main centres of domestication. One centre of domestication was in the Near East, and this is where our taurine cattle come from, cattle without a hump. And the other centre of domestication was on the Indian subcontinent and this is where the zebu cattle come from, the humped cattle.

Jeremy: And the taurine cattle of the Near East, without a hump, and the zebu cattle of India, with a hump, were both domesticated from the wild cattle, or aurochs; but the two groups in India and the Near East separated around half a million years ago, so they were already quite different.

But it is in Africa that the domestic history of cattle becomes really interesting, because there are at least two ways cattle could have got there. By land, walking into Egypt, and by sea, by boat from India.

Olivier Hanotte: The first cattle which actually arrived on the African continent were what we call the taurine cattle, they were cattle without a hump. If today you have the chance to go to the Sahara and to see the rock paintings, the rock carvings, you will see cattle, and you will see that these cattle do not have a hump. So these animals move down, they reach west Africa. And they reached also east Africa but in a patchy way. It was not actually an occupation everywhere.

For this to happen, to have the — Today, the landscape of African pastoralists are basically in Africa, well you have cattle nearly everywhere — you had to wait for the arrival of the second type of cattle, which is the one coming from Asia, the zebu cattle. And this one reached Africa not through Egypt. The entry point was really the Horn of Africa. So most likely they came by boat, essentially around the 7th century AD.

Jeremy: Wow. That's very recent.

Olivier Hanotte: That's very recent! There may have been some minor cattle that came earlier than that, but the main wave only started in the 7th century AD at the time of the development of the Swahili civilisation on the coast of east Africa. What we now have recently discovered, which will be published later, is that in fact, probably 1000 years ago, that there has been intensive crossing between this ancient breed of cattle and the African taurine. You have a cross between an animal from the Near East with an animal from the Indian sub-continent.

But of course, if you look at the geographic position of India, it is actually much more southern than the Near East. So the cattle from India, when they came to Africa, what they did, they brought with them all these adaptations for a much hotter and warmer tropical climate, if you like, than the cattle from the Near East. And that, the mix, the combination of the two, the combination from the African taurine, who — they were the first ones on the African continent — had time to adapt to the local African diseases, with the zebu from Asia, which brought with them the adaptation to a much hotter and sometimes dryer environment, the combination of the two, the cross, allowed then these animals to occupy new lands on the African

continent. This crossing explains the present day success of African cattle in nearly every corner of the continent.

Jeremy: When you think of this, you think of nomadic people essentially, walking around with their cattle. Those cattle are a cross between the taurine cattle from the Near East and the zebu cattle from India, and it is the cross itself that makes them so good at this pastoralism.

Olivier Hanotte: Exactly.

Jeremy: But this is only 100 years ago. Even with artificial selection, I have this idea that it is so slow, and yet what you seem to be saying is that these cattle, after they started crossing them effectively, they really took over.

Olivier Hanotte: You're right in your observation. It actually happened very quickly. So, I want to ask ourselves why.

The reason why it happened very quickly, is because the animal which crossed had evolved the right adaptation before. In other words, what nature did was, it actually selected already present biodiversity. And only what you have to do, you didn't have to invent anything new, what you have to do is to put the piece of the puzzle in the right place. If you don't have the piece of the puzzle or the right place, you basically don't survive. Selection! And if you are not fit, you will not survive, so you will not reproduce. So at the end, only a few will actually have the right combination and they are the ones that are going to take over.

Jeremy: So then the question is: with these breeds that you see around the world, like the black and white Holstein cows or some of the chicken breeds that are very intensively selected, where they are almost genetically uniform, is there a danger then that they could be vulnerable to changes in the environment, or will we always be able to protect them?

Olivier Hanotte: Yes, there is a danger that actually we arrive to a bad hand in terms of adaptability. And the reason is very simple. If you put an animal in an environment like Africa, or even in Europe in the past, human selection but also climatic selection and disease were all part of the same package. When they are part of the same package, well you have to be good at everything, you do maintain diversity for everything, to a certain level.

When you have in mind only a single goal — you want to improve milk production — and you decide that all the other traits, like disease resistance, climatic resistance, or even fertility, you decide that you will handle that through management. You only concentrate genetically on one trait, you obviously lose the other genetics which would have made you adaptable and make you survive in a less managed or unmanaged environment. So there are some present producers who produce a lot, but in a completely artificial management system. These animals, when you airlift them into the African context, they don't survive unless you bring with you the management system of Europe. And this is not sustainable.

If you think about the future, and I think it is very important to think about the future ... we are facing an environmental crisis with Covid-19. But the environmental crises are not just the Covid-19; the environmental crises are climatic change, the environmental crisis that we have to face is also to feed an increasing population. But we have to do all of that sustainably. Whatever direction we decide to take for society, it has to be a sustainable direction, and this is where diversity comes into play again.

Now, if you think about the diversity found in African livestock, what do you have? You do have animals which actually may not be as good in terms of producing food, in terms of quantity — meat, eggs, milk — than the breeds from the commercial sector, but these animals survive with a minimum input. They survive, they reproduce and they actually in a certain sense have fulfilled the needs of the people for centuries.

So the solution in terms of cattle, is basically again crossing. In the past, what has made success, what has allowed cattle pastoralism to disperse and to occupy a large portion of the African continent was this cross breeding with taurine and zebu. For the future, how are we going to address this issue of producing far more food and in a sustainable way? It will most likely be the same. We are to cross the African cattle with these exotic commercial breeds. The two together probably will be the solution for the future for the African countries.

Listen at <https://eatthispodcast.com/livestock>