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I: Hello and welcome to The Big Questions. I'm Alfredo, Senior Staff Writer at IFL Science. In this episode we talk about us and our ancestors to answer why we homo sapiens are the only human species left on the planet. To guide us in this journey we're joined by anthropologist Professor Chris Stringer, an expert in human evolution from the Natural History Museum in London. Thank you very much for joining us. Can you tell us a bit about yourself and your work?

R: Okay. Well, I work at the Natural History Museum in London, and I work on human palaeontology, human fossils. I've been there about 50 years now so I'm almost a fossil myself. It's a long time and I've been lucky enough to see a lot of exciting developments in human evolution studies in that time of course.

I: Wonderful. Thank you very much for bringing your expertise to our podcast. To start, could you please define for us the terms humans and hominins and tell us how many hominins existed on earth?

R: Right, yes. Well, of course it depends who you ask because there are different opinions about how to define these things, but I'll give you my preferred options. So, hominins are the group that includes us and all our relatives back to our common ancestor with our closest living relatives which are the chimpanzees, chimpanzee and bonobo. People think that common ancestor might have lived maybe 7 million years ago, and so everything on our line after that we call a hominin. Then a long way down that line, we eventually get to what we can call humans. The first stages the creatures were very ape-like, they had small brains, and they may not have walked upright the way we do. But as we get to the end of that record, within the last 2 million years we get to things which look much more human and are much more like us today. Even the term human is used differently. There are some people who just use human for us, our species, homo sapiens, so for them even the neanderthals who are close relatives, they wouldn't be called human. I don't agree with that as we're going to come on to later. For example, we know neanderthals interbred with us, so I think that gets us into very murky waters if we start talking about non-human DNA in us. I call humans everything in the genus homo. So, there's this grouping of different species which are in the genus homo, humans, so that's homo sapiens, us, homo neanderthalensis, the neanderthals, and homo erectus. So, those are all in my view human. Anything that's in the genus homo I call human. That covers more or less the last 2 million years of human evolution. And how many species are there? Well, it's a lot. Again, it depends who you ask but in my view there are more than 20 different species in there if we go back across that whole 7 million years. Even within a genus homo there are probably at least ten different species on most people's reckoning. There are some where it's tricky whether you call them human or not depending on which features even, are we talking about a large brain, are we talking about walking upright like us? Some people even put behaviour in there, do they

have complex behaviour? I prefer to leave the behaviour out of these definitions and just talk about what's preserved in the fossils. In terms of humans, yes, at least ten kinds of humans, which is a hell of a lot considering we're the only ones left now.

I: Yes, absolutely. And that is The Big Question for this episode. So, that was 2 million years ago but let's do a big jump forward. Can you take us back to about 300,000 years ago, what and who are the humans from the earth at that time?

R: Okay. So, at that time if we just stick first of all with Africa, we were evolving in Africa and our species underwent most of its evolution in Africa, maybe even all of its evolution, that's not clear, but most of our evolution was in Africa. In Africa homo sapiens was there and we've got fossils that are regarded as early homo sapiens up in Morocco, for example, and all the way down in South Africa at a site called Florisbad. Homo sapiens was already in different parts of Africa. There was also another species of human around and the name varies, but sometimes called homo heidelbergensis after a fossil originally first found in Germany. Homo rhodesiensis, an alternative name for this species because some of the remains were found in what's now Zambia, used to be Northern Rhodesia. Some people don't like that name because it's got the Rhodes in it which associates with the colonialist Rhodes. So, controversy about these names but that's a different species of human. Still quite large-brained and closely related. Then there's something that looks much more primitive we've only learnt about in the last ten years called homo naledi. This species is known just from some cave chambers in a cave called Rising Star in South Africa near Johannesburg. They found remains of hundreds of bones and fossils of a new species that was around about 300,000 years ago. It's kind of human in some ways, the hands and the feet and the legs suggest it was like us, but other parts still suggest that it was climbing around in the trees, and it had a very small brain. That was still around 300,000 years ago which is really a big surprise. That's at least three species just in Africa. Then if we move outside of Africa, we've got the neanderthals. I call them a different species, homo neanderthalensis. They were around in Europe and parts of Asia, and they'd been evolving for a long time there, we think, just as we'd been evolving in Africa over that same time period. Then over in the Far East there are certainly people called the Denisovans and we've only learnt about them in maybe the last 15 years. We mainly know about them from DNA from very fragmentary fossils in a cave in Siberia called Denisova Cave. These fragmentary fossils have yielded up DNA, very well-preserved DNA. We can compare that with our genomes and with neanderthal genomes and it's a different kind of human with again a separate evolutionary history. They were there in that cave from probably at least 250,000 years down to at least 50,000 years ago, so they're the Denisovans. Then in China there are a whole lot of fossils where we don't have the DNA, but it looks like they represent a separate kind of human. They could be the same as the Denisovans. But until we have their DNA, we can't tell. But those people, they've had different names given to them. There's a fossil from Dali in China so they might be called homo daliensis, but there's also a fossil called Dragon Man, homo longi, that was found in the last couple of years. I was involved in studying that one, so maybe the species will be homo longi. So, that's already three in Africa, the neanderthals and the Denisovans, and these Chinese things that might be Denisovans. If we go down to Southeast Asia on the island of Flores, there was a weird wolf species called homo floresiensis, nicknamed The Hobbit because it was tiny and it had big feet, and that was around probably until at least 60,000 years ago in Flores on this isolated island

sort of halfway between Indonesia and Australia. On the Philippines there are fragmentary remains of another species on the Island of Luzon called homo luzonensis. We don't know much about it. It was still there probably 100,000 years ago. It seems to be very small-bodied like the Flores, but it has some other different primitive features, so that's another species. We've got three in Africa, at least two in Asia, neanderthals and Denisovans, and the Chinese things maybe, and then there are two more in the islands of Southeast Asia. That's a lot of humans even around 300,000 years ago and at least five of those carried on until recently. I should have mentioned homo erectus. This is an early species that was around one and a half million years ago and might be our ancient ancestor, and that's usually regarded as being in Africa and Asia, probably in Europe as well later on. It survived a long time, and it was still around in Indonesia maybe 100,000 years ago, possibly later, so there's that primitive species also hanging on. A lot of diversity 300,000 years ago and a lot of it even continuing into the last 100,000 years.

I: **It's quite fascinating to learn how many different humans were out in the world back then. You mentioned that for some of them we have only had a limited amount of fossils. Can we tell how different these species were from our ancestors? Can we just get a rough sketch of they were separated based on DNA? How much can we tell about these species?**

R: Yeah. So, there's only three of them that we can really talk about for DNA, that's us and the neanderthals and the Denisovans and possibly some of those Chinese fossils. All the rest we don't have DNA. Unfortunately, DNA doesn't survive well in hot conditions. Also, it doesn't survive well through time, so beyond 100,000 it's very rare to get any DNA out of fossils. We don't have DNA for some of those earlier things and where they're in hot conditions, we don't have DNA. There is a thing called proteomics which is a growing science now. Proteins survive better than DNA, so you can actually look at fossil proteins in bone and those are starting to be used now to investigate some of these other species and that will help us relate them. In terms of DNA, it's only really three of them that have DNA and they're certainly distinct. We probably had a common ancestor with neanderthals and Denisovans at least 500,000 years ago. Some people push it even further back. The other ones, they're probably less closely related and very different anatomically. I mentioned brain size, for example, we and the neanderthals and pretty certainly the Denisovans had big brains, but naledi and floresiensis had very small brains, basically ape-sized brains like a gorilla or chimpanzee today, so huge variation in brain size alone. In the skeleton I mentioned we have a skeleton which is quite lightly built, we're not heavily muscled. But if we look at the neanderthals, they're very human in terms of walking upright, in terms of their ability, to their hands, their good grasping to manipulate the environment. They were more muscular, they had much more robust bones overall. Their lifestyle was very demanding, and they had a skeleton built for that demanding lifestyle. They're much more robust overall and in the skull, for example, they have different features. They've obviously got this big brow ridge over the eyes, which is something we find in most of those other humans who've got these weird, big brow ridges over the eyes. Lots of ideas about why they're there. We don't have them or only to a limited extent. Some people have argued it's for protection from blows from above the head and other people have said it's some kind of device to spread stress and strain in the skull for the chewing. But actually, some recent ideas suggest it might be more for signalling, that these people, one of their signalling was to stare at each

other. Rather than actually get into a fight, you just had an aggressive stare. So, just like some apes and monkeys will bare their canine teeth, we don't have big canine teeth, but maybe these early humans just aggressively stared at each other, keep away from my food, keep away from my partner. Those aggressive stares, the brow ridge accentuated those stares, so maybe it's there as part of a signalling system. Really, we're at a loss to come up with any better ideas about the brow ridge, but it's there in all these other humans, so that's a distinctive feature that all of them pretty well share compared with us. We've got a high forehead, we've got a [unclear 00:13:16] rounded brain case, a side view looks a bit like a football. Whereas if you look at a neanderthal or homo longi or homo erectus, their brain case is much longer and lower, stretched out and flatter, so this globular brain case is a very distinctive feature of our species. We have a chin on the lower jaw and these other ones tend to have receding lower jaws. Again, why have we got a chin? Nobody really knows. One suggestion is it's a species-specific feature that you notice it and that means we recognise each other as the same species, we've got these nice chins. Another idea is that it's a kind of buttress. So, the middle of the jaw in an embryo and in a child, the jaw is actually divided into two in the midline. The front of your jaw when you're a baby is actually in two halves, and they fuse together. The idea is that that's a point of weakness, so when our muscles work during chewing, our jawbone is stressed. A bit like a wishbone, it gets stressed. We have a buttressing at the front and in the primitive humans and in apes, the buttress is on the inside or the whole jawbone is thickened. But in our case the argument goes that our teeth are smaller, we process our food, so our jaws and teeth get smaller and we speak a lot, we move the tongue around a lot so the buttress has migrated to the outside, which is why we've got that bump on the outside. It's an interesting idea. Who knows if that's the explanation. But the chin is certainly a distinctive feature for us, and the other ones don't have that. There are number of differences and even down to the ear bones, we've got obviously the middle ear bones are concerned with hearing, with transmitting sound to the inner ear. And the inner ear is concerned with processing the sound and also with balance. Those tiny little ear bones, which usually we can't see because they're buried deep in the temple bone, with CT scanning we can look at the shape of them in these extinct humans and incredibly, even those little ear bones are differently shaped. You can tell a neanderthal even if you just [unclear 00:15:31] ear bones, you can say, yep, that's a neanderthal so it's that distinctive. Their ear bones are actually more different from ours than the ear bones are different between a gorilla and a chimpanzee.

I: I love that the reason why all the other human species had a brow ridge was for a potential staring contest and maybe we didn't have the same. So, my next question is how did they die out or, alternatively, how did we survive?

R: You're right, Alfredo, that really is one of the big questions, and I wish I could give you a straightforward answer. We don't frankly know why we're the only ones left. Obviously, some of them may have disappeared before we spread around the world, but we know that within the last 100,000 years homo sapiens having evolved in Africa started to come out from Africa. And there were probably some even earlier little excursions from Africa, but the main movement of people from Africa happened maybe 60,000 years ago. Everyone outside of Africa whose ancestry is outside of Africa originates from that migration which began about 60,000 years ago. And when those people came out, they came out into the territory obviously of the

neanderthals who'd been there a long time. When they got over to the Far East there would have been the Denisovans, these people in China, and probably as they went through Southeast Asia towards Australia there would have been these other species. Now all of those species that were there less than 100,000 years ago disappeared somehow in that period, so it's easy to make a connection with the spread of our species and the disappearance of the other species. Some people make a direct connection, and they say we just killed them all off, that's easy. We were very superior to them, and they were out competed, and they died out very quickly. In fact, the more we know about this time, the more complicated it looks. The only place where we really have enough detail is in Europe and Western Asia for us and the neanderthals. There we've got enough sites with stone tools and with archaeology and with good dating and with fossils to really look at this time period. What we can say is the neanderthals, they had disappeared physically by about 40,000 years ago. Homo sapiens had got into Europe probably in reasonably large numbers in the previous 5,000 years, so there was an overlap of at least 5,000 years before they disappeared. What evidence do we have of their interaction? Well, not really very much. They were close to each other, but we can't put them in the same sites at the same time, but we do know there was interbreeding. I'll come on to that probably next, but let's concentrate on the extinction without the interbreeding, we'll talk about the interbreeding later. We know the climate was very unstable, so it was fluctuating from nearly as warm as today to bitterly cold, even within a few hundred years, and this kept happening. So, even before we came into the neanderthal territory, between about 50,000 and 100,000 years they had suffered these repeated shocks of rapid climate change. That destabilised the environment, not just for them but for everything, plants and animals, and it looks like they had trouble maintaining their numbers in the face of this constant change. The genetic diversity seems to have dropped with evidence of inbreeding from some of the sites with close relatives having to breed, and this probably wasn't good for the gene pool. So, it's possible even without us arriving in their territory they already were to some extent the threatened species. Then when modern humans arrive there, even though neanderthals we know were very capable, and that's again a change of view in the last 20 years, 20 years ago I would have said there were big differences in behaviour, the neanderthals were inferior in many ways, now the gap has really narrowed down. They were doing a lot of complex behaviours that we thought were unique to our species and yet they still disappeared. I think it was probably a combination of things, the environments had hit them, and then this other species arrived that was maybe even just marginally better at doing stuff, at cooperating, at networking across territories, at working complex hard materials. Things like bone and antler and ivory, these materials were all around but the neanderthals didn't make a lot of use of them. They're quite hard to work unless you've got special stone tools. Homo sapiens developed those tools and probably our technology was a little bit better, a little bit more adaptable for rapid changes of climate, for example. So, even having the sewing needle would make a huge difference. If it gets suddenly very cold you can make sewn clothing, you can make tents which are better insulated, keep your babies warmer. All of that could make a difference, something simple like a sewing needle. So, I think that as modern humans spread out, we would have been hunting the same animals as those other humans, we'd have been collecting the same plant resources, we'd have been wanting to live in the best sites, the best cave sites, the best valleys for hunting and gathering. I think there was probably an economic competition going on, and that for me is probably the main reason why we replaced the

neanderthals. For the other ones we've got really very little data of any interaction. We don't know why the Denisovans died out, but we know that within a few thousand years of homo sapiens getting to that region of Siberia, they disappeared. Again, you can make this potential connection. Floresiensis, we don't know what happened to it, and erectus, we don't know what happened to it. By extrapolation, perhaps the same process has happened to those as well, but we've got much less data. We know it wasn't a complete disappearance for some of them, because of course the neanderthals and the Denisovans interbred with homo sapiens. We know that happened in Europe, it happened in Asia, and so you and I probably have around 2% neanderthal DNA in our genomes from the interbreeding. In a sense, the neanderthals haven't gone fully extinct because a bit of them lives on in us. Someone calculated that because we don't all have the same bits of neanderthal DNA, if you add up all the neanderthal DNA in the world today in everyone, you could probably reconstruct 40% of the neanderthal genome without even having a neanderthal just from the people alive today.

I: Wow.

R: Remember there are billions of us around the world today compared with maybe hundreds of thousands of neanderthals. There's more neanderthal DNA around today in the world than there was 50,000 years ago. So, are they really extinct? That's an interesting question.

I: Could we say that they disappear into our gene pool then?

R: I think that's part of it too. In Europe what's interesting is after about 50,000 years we pick up this sign of interbreeding between the last neanderthals and the homo sapiens that are in Europe and Asia. What's interesting is so far, a lot of the early modern human genomes from that period show neanderthal inbreeding, sometimes even within a couple of generations so quite recent interbreeding, but none of the neanderthal genomes show homo sapiens DNA going into them. It's a bit odd. We don't know if the interbreeding only went one way for social reasons or whatever or is it possible that the DNA was successful coming into our species but not going into neanderthals. It could even be things like birth processes. We know the neanderthal pelvis was differently shaped, and I've mentioned that the heads were differently shaped, so is it possible that a homo sapiens mother could give birth to a hybrid baby more easily than a neanderthal mother could give birth to a hybrid baby. We really don't understand that at the moment, we don't know even how the interbreeding happened. Was it basically friendly encounters, did they overlap enough and make some kind of contact that they exchanged partners? Was it that there was warfare and the homo sapiens captured some neanderthal women and then put them in their group and bred with them? Was it that they adopted babies? The neanderthal parents had died and they found some neanderthal babies and brought them in their group and brought them up? All of those things could have happened, and we really don't know the story yet, but it did happen. The same thing happened with Denisovans; we don't know the details of that process at all. But people in Asia have a small amount of Denisovan DNA, and when you go down into islands of Southeast Asia and Australia you have higher amounts. As I say, you and I have about 2% neanderthal DNA. The people, let's say, in New Guinea or Australia, they also have 2% neanderthal DNA because their ancestors spread from where there was interbreeding with neanderthals, they spread across Asia, and then they went down through Southeast Asia. There must have been Denisovans

living there, and they interbred with them and took that DNA with them. People in Australia and New Guinea and the Philippines have maybe about 4% Denisovan DNA in their genomes as well as 2% neanderthal in their genomes, so it's a complicated story.

I: That's so interesting. So, for my last question, you mention our ability to maybe social network across wider distances and between different groups. How does the ability of us being social animals come into play in our survival?

R: Yeah, I think it's definitely a factor. Some people have suggested it's one of the main factors, that we were friendly and less aggressive, at least within our own groups, and that cemented our relationships. So, you do see reasonable levels of interpersonal violence in neanderthals. There are a number of them who got injuries. Of course, some of that could be hunting accidents, but some of them do seem to be the results of probably conflict between groups. Homo sapiens at least within the groups moderated that, so we moderated that aggression, we cooperated more, and that cooperation extended across the landscape. When you look at raw materials, for example, obsidian, which is a very nice material of volcanic glass, natural glass, very nice for making stone tools. Beads which sometimes get transmitted from the coast hundreds or even thousands of miles inland, those networks of exchanges of raw materials seemed to be much wider for homo sapiens than they are for the other humans. That suggests networks of exchange, maybe exchanges of partners. So, homo sapiens look less inbred than the neanderthals were, for example. We're building across the network more widely and that kind of gives you an insurance against the bad times. If the climate changes suddenly and you need to move the [unclear 00:26:36] area, if those people are your enemies, you're in trouble. But if you've actually married into their groups then you can do that more easily. I think that our cooperation at least within groups was part of our success, certainly.

I: Wonderful. Thank you so much for this explanation on why we might be the only human species left, and for taking us through the many changes our species has gone through, as well as those that used to be here.

R: I should just say one more thing. This question of species, I call these things different species and some of your people listening will say, wait a minute, if they're interbreeding with each other, why are they different species? Because certainly at school I was taught that species don't interbreed with each other, but now we know from extensive DNA evidence that lots of closely related species, and we're talking about dogs and wolves and jackals, monkeys in Africa, polar bears and brown bears, they do interbreed with each other to an extent and that's certainly happened. We weren't separate long enough from the neanderthals and Denisovans to develop reproductive isolation. Even though I call them different species and they look quite different in the skeleton, yes, there was still the potential for a bit of interbreeding.

I: The prove of that is that we still have their DNA within in us.

R: Yeah, for better or worse. And it affects us too, some diseases, some immune systems in us are due to the neanderthals.

I: Thank you very much, Professor Chris Stringer, this was a fantastic conversation.

R: It's been a pleasure speaking to you, Alfredo, thank you.

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