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Neanderthals in Leipzig

Most of the human beings alive today have one or two ‘troll children’ among our forebears. A small proportion of our genetic material comes from ‘The Others’ – the people we now know as Neanderthals. This share is slightly less than 2 per cent for people of European descent like myself – the same proportion as if my grandmother’s grandmother had had a grandfather who was a Neanderthal. It is as though a ‘troll child’, fathered by a Neanderthal, were the father of my grandmother’s grandmother.

Naturally that isn’t the case. The father of my grandmother’s grandmother lived in the nineteenth century. The interbreeding of Neanderthals and modern humans, however, occurred much earlier – about 54,000 years ago.

Yet the traits inherited from the Neanderthals have remained with us for thousands of years because the population was so tiny at that time. This meant that a few instances of interbreeding with Neanderthals had a major impact. Moreover, some of the characteristics associated with the Neanderthals were useful, improving people’s chances of surviving and having children of their own.

The scene of our sexual interaction with Neanderthals is likely to have been the Middle East, a corridor through which all humans passed on their way from Africa to other parts of the world. It may well have been Galilee, which archaeological finds show to have been inhabited concurrently by modern humans and Neanderthals. Alternatively, it may have been a little further to the north, possibly in what is now Lebanon.

The Neanderthals were the first to arrive in the region, their ancestors having left Africa several hundred thousand years before us. Traces of Neanderthals can be found from Spain in the west to Siberia in the east. One of the first finds

was made in the mid-nineteenth century, in Germany's Neander Valley, hence the name 'Neanderthals'.

From the discovery in the Neander Valley right up to the last few decades, most researchers believed that today's Europeans were the Neanderthals' grandchildren, figuratively speaking. They thought we had developed here, isolated from other peoples for a long period of time, and had thus developed a typically European appearance, with light skin and straight hair. People in Asia and Africa were thought to have had separate developmental histories; Asians, for example, were believed to be descended from other prehistoric peoples such as Peking Man and Java Man. These ideas, known as the multi-regional hypothesis, are largely mistaken. Yet they do contain a few small grains of truth, as revealed by new DNA technology.

Through his studies of ancient DNA, Swedish-born Svante Pääbo has done more than anyone else to shed light on the early history of humankind. Today he is one of the world's most renowned scientists and the director of the department of evolutionary genetics at the Max Planck Institute for Evolutionary Anthropology, of which he is a co-founder, in the German city of Leipzig.

I visited the Institute twice while working on this book. It is housed in a specially designed, spacious building, with light flooding in through glass walls. A pool encircled by green plants gleams in a central atrium. At the entrance there is a climbing wall four storeys high, built to Pääbo's specifications. This is used by young researchers training for African fieldwork on treetop-dwelling monkeys. Next to the climbing wall stands a grand piano which is used for choir practice. These features go to show some of the Institute's unique character. Researchers here work in disciplines as diverse as psychology, palaeontology and linguistics, seeking to develop an understanding of how we came to be the people we are today. But it is molecular biology and DNA research that lie at the very heart of the Institute's work.

The special laboratory for extracting ancient DNA is situated in the basement, to avoid any unwanted contamination. It is here that Pääbo and his young colleagues strive to further refine their technology. Although they now have many competitors in other countries, the Leipzig group is still a world leader. During the week when I visited the Institute for the second time, they published a study on DNA from an archaic human found in Spain, some 400,000 years old – from a time before even the Neanderthals had emerged.

Pääbo's work is cutting-edge research that drives progress in technology and knowledge. But the fact remains that it was the Neanderthals that made him famous, and it is his increasingly high-resolution analyses of Neanderthal DNA that have made him known to the general public.

When I entered Pääbo's office, the first thing to meet my eyes was a Neanderthal skeleton, squeezed in between the desk and the sofa. It was a composite, made up of copies of various excavated bones. In contrast to the short, powerfully built Neanderthal, Pääbo was tall and lanky, with a long, narrow face.

Newspapers worldwide have dedicated metres of column space to his research and his unusual family background as the secret, illegitimate son of Sune Bergström, the Nobel Prize-winning vice-chancellor (or president, in US terminology) of Stockholm's Karolinska Institute. Pääbo himself has written an interesting autobiography, *Neanderthal Man*, in which he focuses more on his mother, the Estonian refugee and food chemist Karin Pääbo. When he was 13, she took him on a journey to Egypt, where he was seized by a deep fascination with mummies. That was how his career in research began.

He grew up in Bagarmossen, a suburb south of Stockholm, learned Russian at the Swedish Armed Forces' Language Institute (one of their most demanding courses) and went on to study Egyptology and Coptic at Uppsala University. A few years later, he abandoned Egyptology and switched to medical training. After four years of medicine, he began to conduct research in cell biology.

His day-to-day job involved studying a viral protein. In secret, he was also trying to isolate DNA from mummies thousands of years old. His boss knew nothing of this until Pääbo's first scientific article was well on the way to publication. The article appeared in an East German journal because the first mummies Pääbo had investigated came from a museum in East Berlin. It later transpired that what Pääbo had thought to be sensational DNA from a mummy was probably mostly the result of contamination by our contemporaries. But at least the idea was there. He had shown that DNA can survive in tissues several millennia old.

No one in the West took any notice of the East German publication. However, one year later Pääbo published another article, this time in the British journal *Nature*. This, by contrast, attracted great attention. One of the consequences was a letter from Allan Wilson of the University of Berkeley in California, one of the world's foremost specialists in evolution and DNA at that time. Wilson asked whether he could come and work in 'Professor' Pääbo's laboratory. Pääbo, who had just turned 30, was still working on his doctoral thesis, and he was far from having a lab to call his own. Instead, it was agreed that Pääbo would come and research at Wilson's laboratory in California, where Wilson and his colleagues had started to use DNA technology to unravel the early history of humankind.

By 1987 they were able to publish the first study using DNA technology to show that everyone living now ultimately originates from Africa. Our common foremother was a woman living in Africa some 200,000 years ago, who is usually known as 'mitochondrial Eve'. The name, of course, is a nod to the biblical creation myth. Mitochondria are discrete structures within cells that contain a small amount of DNA. Initially, all DNA analyses of the origins of humankind were based solely on mitochondrial DNA. This is because it is much easier to analyse than DNA from the cell nucleus (nuclear DNA), there being thousands of mitochondria in most cells, but only one nucleus. One limitation is that mitochondrial DNA can only be used to trace the origins of

an individual in the maternal line, as we inherit our mitochondria solely from our mothers.

So by 1987, the technology available was already sophisticated enough to trace ‘mitochondrial Eve’, though the methods that were used appear unbelievably labour-intensive by today’s standards. The young researchers from Wilson’s laboratory visited maternity hospitals all over California to collect placentas from women from different parts of the world. Laboriously, they isolated the DNA from these placentas and calculated the results with their primitive computers.

Linda Vigilant, who is now married to Svante Pääbo, was one of Allan Wilson’s postgraduate students. She conducted a follow-up study of mitochondrial Eve a few years later. The low-performance computers of the time were still so slow that it took a week to perform the calculations.

Source: Phylotree 2015

*Figure 1 **Foremothers of Africa.** ‘Eve’, who lived in Africa around 200,000 years ago, became the foremother of everyone living today. About 60,000 years ago, one of the lines of her descendants left Africa and subsequently dispersed worldwide.*

But DNA technology had moved on considerably. A researcher in California had developed a technique for copying DNA, known as PCR (polymerase chain reaction), for which he was awarded the Nobel Prize a few years later. This method enabled researchers to work on single strands of hair, rather than having to use an entire placenta. Anthropologists from all over the world helped to supply strands of hair from a very wide range of populations. And the results of the first study were confirmed. About 200,000 years ago, there was a woman in Africa from whom everyone alive today is descended. She was thus our common foremother.

A few years later, in 1995, American researchers published their findings about mitochondrial Eve's male counterpart, known as 'Y-chromosome Adam'. Thanks to improved DNA technology and increasingly powerful computers, the Y chromosomes of men from all over the world could now be compared. Y chromosomes contain far more DNA than mitochondria, and they are passed on from father to son only. This means they can only be used to reconstruct the direct paternal line in a family tree. The results revealed that a man living about 200,000 years ago was the forefather of all men living today. Y-chromosome Adam lived in Africa too.

There was no longer any room for doubt. The multi-regional theory was dead. The origins of modern humans lie in Africa.

DNA technology advanced in leaps and bounds. Pääbo and others succeeded in developing methods for analysing samples several thousands of years old. By conducting tests on animal fossils, he learned how to keep samples uncontaminated. The challenge was to exclude any dust, old bacteria or traces left by people who had touched the fossils in recent times.

After California, he was offered a post as a professor at a zoological institution in Munich. There he impressed on his two doctoral students that they must avoid all forms of contamination, irradiate the whole laboratory with ultraviolet light every night, go straight to the special laboratory every

morning without visiting any other laboratories with DNA samples, and take a whole range of other precautions.

In the summer of 1997 Pääbo published a DNA analysis of the world's most famous Neanderthal – the very skeleton that had been discovered in the Neander Valley in the mid-nineteenth century, giving Neanderthals their name. This time, the results were far more reliable than those obtained from the ancient mummy 12 years previously. The analysis, based on mitochondrial DNA, showed clearly that Neanderthals cannot be the forebears of modern Europeans. We are not their great-grandchildren; at least, we are not descended directly from them in the maternal line. It would be more accurate to compare our relationship with that of two groups of cousins whose common origins lie much further back in history.

This study had an enormous impact. Pääbo became a science superstar, particularly in Germany, where Neanderthals have had a unique status since they were first discovered in the nineteenth century.

Unfortunately, I have to admit I missed the news about this revolutionary study. I had started my job as *Dagens Nyheter's* science editor just a few months previously and had not yet had time to acquaint myself with all the journals a science journalist needs to monitor. Nor was I yet on the right lists to receive advance warning of press conferences, and invitations to them.

But a few weeks later I met Pääbo at a seminar on the new gene technology, held in Oslo. We had dinner together, and my interest in this field of research was fired. Since then I have interviewed Pääbo many times, attended his lectures and reported in *Dagens Nyheter* on the publication of his studies in the world's leading scientific journals.

After the first mitochondrial analyses, he went on to analyse nuclear DNA, which, as noted above, is far trickier. However, a successful analysis helps provide a far fuller

picture, as mitochondria contain no more than a few thousandths of a per cent of our total DNA. Moreover, they can only be passed on through the maternal line. The rest of our DNA, located in the cell nucleus, is inherited from both parents.

The first preliminary mapping of nuclear DNA published by Pääbo and his team in 2009 confirmed the picture that had emerged from the first analysis of mitochondrial DNA – that Neanderthals are *not* the forebears of modern humans. Rather, they should be seen as our genetic cousins.

But then came further input. More sophisticated analyses brought unexpected results. Pääbo himself was startled. In May 2010 he and his collaborators published an exhaustive analysis showing that Neanderthals and modern humans had in fact produced offspring. Features inherited from Neanderthals live on in us; the Neanderthals are not completely extinct.

Since then, the technology available for analysing prehistoric DNA has advanced even further, and it can now produce as high-definition an image as if researchers had examined you or me. The conclusions they have drawn can be summarised as follows.

It turns out that Neanderthals are our forebears after all, though they account for only about 2 per cent of our genetic make-up. When anatomically modern humans migrated from Africa to other parts of the world, they passed through the Middle East, including the region of today's Israel known as Galilee. The area was already inhabited by Neanderthals. They must have lived in parallel with anatomically modern humans in the same region for some time. People from the two groups had sex with each other on a number of occasions, producing offspring who were able to have healthy children themselves.

Modern-day people whose origins lie in Asia, Australia and the Americas have slightly more Neanderthal DNA than Europeans. Just over 2 per cent of their DNA is of Neanderthal origin, while an average European has just less than 2 per cent. This is probably the result of further interbreeding

between Neanderthals and modern humans further east in Asia.

Moreover, the people who migrated eastwards into Asia, New Guinea and Australia appear to have interbred with another kind of archaic human called the Denisovans. Modern inhabitants of New Guinea have up to 6 per cent Denisovan DNA in their genetic make-up, and a smaller percentage can also be found in the Chinese population.

Characteristics inherited from Neanderthals can be detected even among Africans. This applies even to traditional groups such as the Yoruba of West Africa and the Mbuti people of the Democratic Republic of the Congo. However, the proportion is minute in such cases, and can be explained by the fact that some Europeans and Asians returned to Africa in the course of history.

There are commercial firms today selling DNA tests that, they claim, can reveal the percentage of Neanderthal or Denisovan DNA in an individual's genetic make-up. But Pääbo describes these tests as unreliable. The margin of error is so great that the result is next to meaningless. In retrospect, he regrets that his own team failed to apply for a patent on such tests; they would have been able to guarantee far higher standards.

Presumably it was an advantage for a young child living in the Middle East 54,000 years ago to have inherited certain features from Neanderthals. Such children may well have been healthier and more resistant to infection than others. Those of our forebears who migrated from Africa to the Middle East were part of a small group, possibly just a few dozen or a few hundred individuals. A few generations of breeding solely within the group had seriously depleted their immune defence. Inbreeding is bad for immune defence, so it is a good thing to have new, fresh blood from outside.

The American immunologist Peter Parham has identified a group of genes in our immune system that appear to have been inherited from Neanderthals. These genes must have helped the Troll Child and his peers to survive 54,000 years ago. Today, the same genes may be partly responsible for

making the immune system too effective; as a result, it goes haywire in some cases, increasing the risk of autoimmune diseases such as multiple sclerosis and type 1 diabetes.

Researchers have identified two Neanderthal genes that affect the capacity to transform fat in the diet. In our time, bearing one of these two genes increases the risk of contracting type 2 diabetes. This disease is closely linked with being overweight, a major problem today. But things were different 54,000 years ago. For the first modern Europeans, it was an advantage for their bodies to be able to assimilate as much fat as possible; that reduced the risk of dying of starvation.

Svante Pääbo's research team has also identified a handful of other genes that seem to have been transferred from Neanderthals to modern human beings. They all affect a substance called keratin in our hair and skin. Both Asians and Europeans seem to have inherited variants of these keratin genes from the Neanderthals, but oddly enough, the sets of keratin genes concerned are different. It is not yet clear exactly how Neanderthal genes affect our hair and skin. If I were going to lay a bet, however, I would wager that straight hair is one of the characteristics inherited from the Neanderthals.

Pääbo himself prefers not to speculate about the appearance of Neanderthals' hair and skin. Today, other DNA researchers have developed genetic tests that provide clues about the colour of their skin, eyes and hair. A Spanish research team claims to have identified the hereditary disposition for red hair in one Neanderthal individual. Pääbo, however, thinks these tests are still far too unreliable for him to publish such information. During our interview I tried to press him on this point, arguing that the colour of Neanderthals' eyes, skin and hair would be sure to interest the general public. This kind of information would give a more vivid picture of what we experienced when we encountered Neanderthals.

Pääbo was not swayed by this argument. However, he did reveal something that has not yet been published: none of the Neanderthals he has analysed himself seem to have the genetic make-up associated with red hair. The Neanderthal

individual that he has examined using the most high-resolution analysis, found in a Siberian cave, was probably dark-haired.

He was more comfortable talking about the approximately 87 gene variants that, though present in nearly all modern people, have not so far been found in any Neanderthals. The gene that has been researched in most detail is known as FOXP2.

There is a family living in Britain with several members of different generations who all have a serious language disability. All these individuals have a flaw in this particular gene, which clearly affects the ability to speak. This gene differs in just one small point between mice and chimpanzees. The difference between chimps and Neanderthals amounts to two points. In principle, modern humans and Neanderthals have identical FOXP2 genes. However, there is one tiny difference, discovered by Pääbo and his collaborators. It was difficult to find, being located well outside the gene itself, but it appears to have a significant impact on how the gene functions.

The Leipzig research group has developed special experimental mice bearing the human variant of the FOXP2 gene. Their squeaks are different from those of ordinary mice, and they have better memories. The difference lies in a particular kind of memory known to psychologists as ‘procedural memory’. It involves the same mechanism we use when learning to ride a bike or dance; to begin with we have to think about each individual movement, but after a while we have internalised them. We have them at our fingertips – or rather in our cerebellum. We can make the movement automatically, without having to think about it. Learning to speak is no different.

It is reasonable to conclude that Neanderthal people could also talk to each other at some level – but not as we can.

Svante Pääbo tries to stick scrupulously to his scientific findings and to avoid speculation. However, there is a person who has not suffered from any such hang-ups when it comes

to speculating about our encounters with Neanderthals – the American author Jean M. Auel. Her books, starting with *The Clan of the Cave Bear*, have sold in their millions. The first book in the series, which came out in 1980, describes how orphan Ayla is cared for by a different race of people. When Ayla grows up, she is repeatedly raped by the clan chief's son and gives birth to a son who is thus half Neanderthal, half modern human – this is known as a hybrid.

As regards hybridisation, you could say Auel was 30 years ahead of DNA research. When she wrote the book, there was no reliable scientific evidence of any such phenomenon. There were only individual skeletons, bones and teeth, regarded by some researchers as transitional forms.

Various other aspects of Auel's imaginative story are clearly mistaken. For example, she depicts the modern humans of our type as being blond and light-skinned, while the Neanderthals are described as being dark. But at the time the two met, things were probably the other way round. After all, anatomically modern humans had just left Africa, while the Neanderthals had developed in Europe and parts of Asia for several hundred millennia. Light skin improves people's chances of surviving in northerly latitudes.

Auel's descriptions of the Neanderthals' sign language and rigid social system are entertaining, and many of her interpretations are thought-provoking. She has clearly done her homework on archaeology, anthropology and botany. But we need to remember that her books are stories, not scientific works. Most of their content is pure fantasy.

One of the reasons why the books have sold in such enormous numbers, especially among teenagers, is the many sex scenes some of them contain. Although the descriptions are empathetic and very detailed, their tone is acceptably innocent. The name given to consensual sex is 'Pleasures'. But Auel's descriptions of sex acts between the heroine Ayla and the Neanderthal man are less pleasant. They involve a series of brutal rapes.

Over the last two years, when I told friends and acquaintances about the book I was writing, the question

most frequently raised was what form sexual relations would actually have taken in practice. Most of those who allow themselves to speculate suggest the answer was rape, which tends to be my personal view. But such a scenario really provokes and upsets quite a few people. Some say there is absolutely no justification for speculating about issues that science can never settle conclusively. One of my closest friends accused me of taking a negative view of humankind. 'Maybe a Neanderthal boy and a modern girl fell in love with each other – that's just as feasible,' she commented.

Or, as a young female student said to her professor: 'If they decided to have children together, they must have known each other for quite some time.' Like so many other people, she based her reasoning on her own views on sex and morality.

The professor in question was Jean-Jacques Hublin, director of the department of human evolution at the Max Planck Institute for Evolutionary Anthropology in Leipzig. He is inclined to think that the encounters between Neanderthals and modern humans were over within a few minutes; his view is that they were acting in desperation.

Hublin's office is one floor down from Pääbo's, and it is also dominated by a Neanderthal. His specimen has a little more flesh on its bones; it is a white plaster bust displaying carefully reconstructed musculature. The bust was created back in the 1920s on the basis of the information then available, and in essentials it is still completely in line with the latest research.

Looking at the jutting, broad-nosed face impressed upon me even more just what a gulf there was between the Neanderthals and us. In my introductory story about the woman in Galilee who fell pregnant, I compared Neanderthals with trolls, the creatures that populate our old folk tales. This was not because I think it particularly likely that our troll myths originated in 40,000-year-old observations from real life. Rather, an encounter with a sizeable troll is something we can more or less imagine. The Neanderthals resembled us much more closely than today's chimpanzees do – but the difference was nonetheless considerable.

'I certainly don't think modern humans and Neanderthals got on with each other. I imagine they kept out of each other's way as much as possible,' says Hublin. His scientific discipline, palaeontology, involves attempting to reconstruct what happened thousands of years ago on the basis of fossil bone finds. Such research inevitably entails a degree of uncertainty. The world's foremost palaeontologists have somewhat different views on the differences between modern humans and Neanderthals and on the forms that encounters between the two groups took. Where opinions diverge, I have taken Hublin's line in this book. His position at the Max Planck Institute is unique. Working in close collaboration with DNA researchers, primatologists, archaeologists and anthropologists enables him to constantly update the information that can be gleaned from ancient bones.

The most ancient finds outside Africa of what are called 'anatomically modern humans' were discovered in Israel and are nearly 120,000 years old. But Hublin stresses that these archaic humans had not yet really developed into people like us. Presumably they died out without leaving any descendants. It was not until about 55,000 years later that a new wave of people migrated out of Africa (or possibly from the Arabian Peninsula). This time they were almost completely modern, with all that that implies in terms of skeletal shape and abilities. Israeli researchers have found a cranium from this group of modern humans in the Manot cave in western Galilee.

The first thing that happened when these modern humans left Africa was an encounter with Neanderthals. Neanderthal remains have been found a mere 40 kilometres (25 miles) east of the Manot cave, in the Amud cave in the hills above the Sea of Galilee.

Hublin stresses how thinly populated both Europe and Asia were at that time. The modern humans who had just arrived were not numerous, and the Neanderthals were under heavy pressure. The two groups can hardly have intermingled at watering holes; rather, they would have observed each other at a distance. They had sexual relations on a number of

occasions. A small number of hybrid children were born and survived. A little later, the Neanderthals died out.

Hublin is convinced that they became extinct because we arrived on the scene. They died out first in the Middle East and later in the Caucasus, Siberia and Europe. We outcompeted the Neanderthals thanks to superior hunting methods and greater mobility – or we simply killed them off. Some researchers propose other possible explanations; for instance, we may have survived periods of cold and volcanic eruptions more successfully because we were better at making warm clothes out of pelts, using a needle and thread.

In Hublin's view, all these suggestions are excuses. The Neanderthals had survived ice ages and cold spells for hundreds of thousands of years. Sometimes their numbers fell drastically, but there was always a resurgence when the climate grew warmer – until we arrived. According to Hublin, the only reason for the alternative explanations is to avoid confronting us with the truth – that we actually wiped out an entire group of human beings. The Neanderthals had lived in Europe and Asia for several hundred thousand years. Then we came and took over. (There are at least two similar cases of eradication of other archaic humans when *Homo sapiens* later migrated further eastwards within Asia. Once we had arrived, both the Denisovans and the pygmy-like *Homo floresiensis* on the Indonesian island of Flores disappeared.)

While individual Neanderthals were physically stronger than us, we outdid them in other areas. Presumably we had superior powers of speech, as indicated by our slightly different FOXP2 genes. Language made it easier to maintain more extensive and cohesive networks. Finds of shells and rare stones show that some modern humans belonged to networks extending over 500 kilometres (310 miles), while Neanderthals exchanged artefacts over far shorter distances.

There are one or two finds suggesting that Neanderthals buried their dead. But chimpanzees, too, sometimes cover their dead with twigs and branches. The claim that Neanderthals laid flowers in graves, an assertion made on the basis of a find in Iraq, is hotly contested. In contrast, there is

much incontrovertible evidence that modern humans went to considerable lengths to bury their dead and provide them with grave goods.

One other major and very clear difference is that modern humans played musical instruments and produced figurative art. There are a few simple patterns of lines that may have been incised by Neanderthals in Spain and by other, even earlier archaic humans on Java. But art representing animals, people and imaginary figures emerged only with modern humans.

The world's most ancient examples of musical instruments and figurative art have been found in Europe. The fact is that my forebears – in the direct maternal line – were among the anatomically modern, musical and artistic humans who first colonised Europe. This is revealed by DNA technology.

The year after my first meeting with Svante Pääbo, I went on a fact-finding trip to Iceland and visited deCODE Genetics in Reykjavik, where I interviewed another pioneer in DNA research, Kári Stefánsson. He was then in the process of setting up the genetic research company deCODE, based on two special sets of circumstances. Firstly, Iceland is an island where people have lived in relative isolation; secondly, many Icelanders have an interest in genealogy. Some of them can trace their ancestry as far back as the ninth century, when the island was first colonised.

At the time we met, Kári Stefánsson was a tall, fair-haired and strikingly elegant man in his fifties. Interviewing him was a curious experience, as other journalists have reported. It is his way to start by being singularly impertinent; then, if he thinks the journalist measures up, he changes tack, becoming friendly and opening up.

Fortunately I passed Kári Stefánsson's test. I got to spend a long time in his office, look at the fine maritime painting on the wall and listen to his plans. He gave a demonstration of his new software program, based on the exhaustive

information that he had had a number of women copy from Iceland's church records. Tap a few keys, and you could see your own family tree unrolling centuries into the past, and study your relationship with other Icelandic families. That may sound trivial in the light of today's technology, but it was sensational in 1998.

DeCODE's researchers entered the information from these family trees in combination with DNA analyses from a large number of Icelanders. At the time, there was a heated debate on Iceland about the ethical and legal rules to be applied. One of the issues discussed was to what extent deCODE should have access to biological samples from the medical sphere. The debate calmed down eventually, and the company was granted extensive rights, but new legislation was also adopted that imposed certain limitations. Generally speaking, ethical regulations have become more stringent in most countries since the more Wild West-like conditions under which DNA research was conducted in the 1980s and 1990s.

Since the company's inception, Kári Stefánsson and deCODE's researchers have produced a great many scientific findings, particularly about certain gene variants that can increase or reduce the risk of particular diseases. In purely scientific terms, their work has been a real success story. They publish articles in major medical journals virtually every month. However, they have been less successful in business terms; though deCODE was supposed to be a commercial enterprise, it has never made a profit. In 2009 the firm went bankrupt and was taken over by interested parties from the US biotechnology sector.

Before that happened, deCODE began to sell genetic tests to private individuals on the internet, to make some money. I bought one of the tests, which was the most comprehensive that a private individual could purchase at that time. It covered a million 'items' in my DNA make-up and cost about SEK 15,000 (around £1,400). My reason for spending so much money was that I was doing research for my book *Vikten av gener* ('The Weight of Genes'), which came out in 2011.

I wanted to know how I would react to being told my risk of developing particular diseases.

In fact, all the medical information I received had very little impact on me. There was a slightly higher risk in some areas, and a slightly lower risk in others. For example, I have a slightly higher risk than average of developing certain types of cancer. One of them is skin cancer, which – being blonde and very fair-skinned – I could have worked out for myself.

I was also told I have the capacity to digest lactose, which means I can drink fresh milk – a common feature among northern Europeans, but one that is unusual in many parts of the world. That was hardly news to me; I had known for a long time that I can digest milk.

There was another piece of information that I found far more fascinating, something I could never have predicted. I discovered that I belong to haplogroup U5.

DeCODE's technicians had examined the DNA located in my mitochondria, the tiny structures within cells that you can only inherit from your mother, which are passed on virtually unchanged from mother to daughter over many generations. Sometimes mitochondrial DNA does undergo small changes – mutations – that make for slight variations between one individual and another. Such variations can be classified into genealogical trees. A single haplogroup corresponds to a particular branch of the tree that has a common origin. In other words, all the branches and sub-branches that share this origin have a common female ancestor. This enabled researchers back in the 1980s to trace the maternal lineage of the whole of humanity right back to our primeval foremother 'Eve', who lived in Africa some 200,000 years ago.

Now I learned that I was descended from one of 'Eve's daughters', who is known to researchers as U5. You might also say I am one of the daughters of 'Ursula', as group U5 is sometimes called. The name comes from a book published by the British geneticist Bryan Sykes in 2001 to popularise contemporary DNA research. His book was heavily criticised by other researchers even at the time of publication. There

have been tremendous advances in research since then, so the book's contents are even less valid now than they were then. But since I like the name Ursula, I'll stick with it.

What the researchers were able to tell me when I got my results from deCODE was that the mutations typical of U5 were already present in Europe's early hunter population. That means that the woman we can call Ursula was an Ice Age hunter and belonged to the first people who colonised Europe.

I told two of my relatives with the same mitochondrial DNA about my results, and straight away their imaginations began to run riot. 'I've always liked to go rambling,' said one. 'You can tell we're descended from hunters,' said the other, who spends a good deal of free time hunting.

I explained that the fact that we belong to group U5 has very little – if any – impact on the traits we display. Mitochondria account for just a few thousandths of a per cent

Source: van Oven 2009, Phylotree 2015

Figure 2 U is spread by Ice Age hunters. One of the daughters of 'Eve' is known as U and probably lived in the Middle East. Her descendants spread throughout Ice Age Europe, and into Asia and North Africa.

of our DNA, and the characteristics we inherit have been diluted many, many times since our foremother Ursula made her way into Europe.

It has more to do with feelings. We can think of our mother, grandmother, our grandmother's mother – and then imagine another thousand generations of daughters and mothers. In my case, that takes me back to the Ice Age people who played the world's oldest known flutes, who created the famous cave paintings, developed sewing needles and domesticated dogs.

I decided to travel and take a closer look at how my relatives lived.

The Flute Players

I arrived in the Swabian Jura on a sunny September day with the tree-clad slopes glowing in shades of yellow and red. My companion was a young archaeologist from the University of Tübingen.

At the entrance to the Hohle Fels cave we also met a local guide, Rainer Blumentritt, an elderly man who had discovered one of the local caves in his youth. Ever since that time, he has followed the work of the professional archaeologists at close quarters.

It was at just this time of year, in early autumn, that the first Europeans would have come here too. Here, in the limestone caves, they could seek shelter for the winter, and it was here that they could hunt reindeer when the animals had most meat on their bones and were migrating in great herds.

A few steps inside the mouth of the cave lies the chamber where these people lived. It looks like a cramped space, given that there were between 20 and 30 individuals in a group. They must have been crammed in together. But the young archaeologist accompanying me points out that it was probably warm and cosy as well. The fact that it was cramped made it easier to retain warmth during the cold winters of the Ice Age.

Archaeologists have dug out layer upon layer, excavating a total of several metres. They have found traces of Neanderthals right at the bottom, after which there are no human remains to be found for several centimetres. Above that are numerous traces of modern humans like you and me. The most ancient layer belongs to a culture that archaeologists know as the Aurignacian, identifiable by the way in which its people fashioned their stone tools.

According to the most recent efforts to date such remains, the people of the Aurignacian culture arrived in central Europe some 43,500 years ago. The first traces they left are

to be found in Austria, at an archaeological site called Willendorf. The oldest finds in the Swabian Jura are nearly as ancient.

Hohle Fels is not just a small cave where people once lived. My companion has prepared me for viewing what he calls 'the cathedral of the Ice Age'. And indeed, the inner chamber does exceed all my expectations. The mountain opens out into a vast chamber reminiscent of nothing so much as the interior of a mediaeval church. Dim lamps glow in niches along the walls. Though they are electric, I am sure the light resembles that of the torches people used during the Ice Age.

The young researcher from Tübingen and I walk around in awe, admiring the great chamber. You can climb up onto a shelf, as if in an amphitheatre. Then – quite unexpectedly – we hear the limpid tones of a flute. The local guide has switched on a recording relayed through loudspeakers. The acoustics in the high-ceilinged chamber are extraordinary. So this was what it sounded like when my forebears held their ceremonies.

The flute we can hear in the recording is a reconstruction fashioned out of mammoth ivory. You can still buy ivory from extinct Siberian mammoths preserved in the permafrost – and it's completely legal.

German archaeologists have found fragments of a total of eight flutes in Hohle Fels and the nearby caves of Geissenklösterle and Vogelherd. At a museum in nearby Blaubeuren you can listen to the sound produced by reconstructions of these instruments. Four of the flutes are made out of bones from birds' wings. They sound more or less like someone blowing into a bottle – a very hollow sound. Bones from swans' wings make higher-pitched sounds, while those from vultures are larger, making for flutes with a deeper pitch.

Making a flute out of the hollow bone of a bird may not appear to be a very sophisticated process; all that is necessary is to cut off the bone and drill holes at the appropriate points. It is the four ivory flutes, which produce a sound

rivalling that of a silver flute in clarity and purity, that are truly mind-boggling. Carving a flute from a substance as hard as ivory called for great skill. You had to split a mammoth's tusk in half, scoop out the inside, and stick the two halves together again, forming a completely airtight join. The Aurignacians probably used resin as glue. Observing the positioning of the holes enables us to imagine what the music they produced would have sounded like.

Doubtless human beings have been singing and dancing since time immemorial, far longer than since the point when we first left the African continent. But the flutes from the Hohle Fels caves are the oldest musical instruments of which there is firm evidence. Researchers in Slovenia claim to have discovered an even more ancient bird bone with holes, which they believe to be a flute made by Neanderthals, but that find is surrounded by controversy. Nearly all other researchers are sceptical; they think the holes in the bone from Slovenia were produced by natural causes, perhaps by the bite of a hyena.

There is a consensus, however, that the Aurignacians in the Swabian Jura played the flute.

Not only did they have music in their lives, but they also created statuettes. Archaeologists working in the Swabian Jura have found around 50 figurines fashioned from ivory and stone.

The largest of these is the Lion Man from the Hohlenstein-Stadel cave, an ivory figure with a head like that of a lion but the body of a man. It was made nearly 40,000 years ago and is about 30 centimetres (12 inches) tall. A contemporary reconstruction shows that it must have taken about six weeks – for a skilled and experienced person working all day long in full daylight – to make.

In Hohle Fels, that great Ice Age cathedral, archaeologists have discovered a smaller lion man just 2.5 centimetres (one inch) tall that is more simply executed. Other finds from the same cave include a little ivory waterfowl, possibly a loon,

and a particularly well-endowed female figure that is even older than the Lion Man and has been named 'the Venus of Hohle Fels'. She has enormous breasts, and her genitals are clearly marked by a deep cleft between her legs.

For a nomad constantly on the move between different dwelling places, it was practical for artistic artefacts to be small and easy to handle, and light enough to carry. We do not know exactly how they were used, but it requires no great leap of the imagination to see the connections between these art objects and shamanistic beliefs studied by ethnologists over the last 150 years among Swedish Sami, Siberian nomads, Native Americans and the South African Bushmen (also known as the San people).

The cave lion was the largest and most dangerous predator that posed a threat to our forebears in the Swabian Jura. They certainly both feared it and admired its strength and speed. There are many descriptions of how shamans take on the shape of an animal in their ceremonies, often using masks to do so. It is not much of a stretch of the imagination to see the cave lion as part of this repertoire. Waterfowl, too, often play a special role in a shamanistic world view. This is because of their ability to make their way freely between the three levels of the universe; they can fly and thus reach the heavens, they can walk the earth like humans, and they can dive into the depths to reach the underworld.

The large-breasted female figures appear in both Europe and Siberia throughout the nearly 30,000 years of the Ice Age. They may have had a place in female rites around fertility and giving birth. That, at any rate, is the view of Jill Cook, a curator of Stone Age art at London's British Museum.

Nicholas Conard, a professor of archaeology at the University of Tübingen who is in overall charge of the excavations at Hohle Fels, takes a somewhat different view. He prefers to extend the significance of these female figures to encompass fecundity in general, including the whole of nature and the wild animals that were people's quarry. He has suggested that Angela Merkel, the Christian Democrat German chancellor, should wear a replica of the Venus of

Hohle Fels around her neck. She has demurred so far; perhaps the figurine's clearly defined genitalia are a little too provocative for the circles in which she moves.

Some of the art objects from the Swabian Jura are more ancient than any other figurative art anywhere in the world. There are, of course, non-figurative motifs that are tens of thousands of years older than the objects found in Swabia, such as the zigzag patterns on stones from Blombos in South Africa, which have been dated as at least 75,000 years old. But the figures from the caves in southern Germany show that over 40,000 years ago people in Europe were able to depict both creatures that actually exist in real life, such as waterfowl, and imaginary beings, such as the lion men. They must have had mental powers just like ours today.

Conard has advanced the rather provocative proposition that this figurative art first emerged when humans reached the region that is now Germany. He hypothesises that new challenges, such as a cold climate and rivalry with groups already living there, triggered abilities that had hitherto lain dormant. He concedes that people were discovering figurative art in other places too, but argues that those in Swabia were the first to do so.

Conard is aware that his hypothesis is a provocative one. He says he is quite ready to abandon it as soon as archaeologists in other countries find indisputable proof of figurative art or musical instruments that predate the Swabian finds. But the reason why the oldest figurative art and the oldest musical instruments have been found in Germany may be that archaeologists have spent more time searching there than in most other places on earth. That was my own view when I met Conard in Tübingen in the autumn of 2013.

And one year after my visit, strong indications emerged that he is mistaken. An international team of researchers published new information dating cave paintings from the Indonesian island of Sulawesi. The most ancient paintings, it transpired, are some 40,000 years old – about as early as the very oldest paintings in European caves, and nearly as old as the oldest statuettes from Swabia.

When I asked Conard to comment on the new dates, he conceded that people on the other side of the earth were able to create art just as early as those dwelling in the caves of Swabia. However, he claims that the art found in Indonesia and that of Swabia may have developed in parallel, each quite independently of the other. He is now quite alone among the world's leading experts in human evolution in holding this view. Most believe that art and music were already part of our baggage when we left Africa some 55,000 years ago. Culture has followed us on our wanderings ever since, both eastwards and westwards.

I am nonetheless convinced that Conard has an important point in viewing art and music as playing a decisive role in our early ancestors' ability to stay together and survive. But I believe that was the case in Africa, Europe and elsewhere. Creativity and artistic ability have been so crucial to our survival that these abilities are written into our genes – despite the dark downside.

Self-expression through art, music and storytelling is one of the main forces that drive human beings. That was so during the Ice Age, and it remains so today. Yet some of us pay a high price for the continued existence of these features in the population.

Talents such as being able to paint, play music and tell stories are in part hereditary. Families in which such gifts are common also tend to be affected by psychotic conditions such as schizophrenia and bipolar disorder. Both these conditions affect about 1 per cent of the population worldwide, in all the countries that have been studied. They can be very disabling. Relatives of people affected by schizophrenia are often successful as artists and musicians. Unfortunately, that does not apply to the individuals suffering from the condition, as it limits their capabilities to such an extent. People with bipolar disorder more often succeed in creative occupations themselves, and the same is true of close family members.

One of the first people to observe this correlation was an Icelandic researcher called Jon Love Karlsson who published a groundbreaking study back in 1970. His methods leave something to be desired by contemporary scientific standards. He based his research on Iceland's well-documented genealogical information, which – as mentioned in the previous chapter – is probably more comprehensive than anywhere else in the world. This information was compared with the records of patients at Reykjavik's mental hospital and the Icelandic version of *Who's Who*.

Karlsson believed that the risk of schizophrenia was governed by just two genes. Today's DNA research has shown that it actually depends on hundreds of genes, in conjunction with unknown environmental factors. But the link between creativity and psychotic disorders has been confirmed, and that applies to the most recent, largest and best conducted studies.

Many of the gene variants involved emerge as entirely new mutations when a new life comes into being. This is cutting-edge knowledge that has revolutionised research into schizophrenia and a number of other psychotic disorders. The same calculations of new mutations also play a decisive role when DNA is used in genealogy and research into the history of humankind. If you know how many mutations accompany each new baby, you can work out the speed of human evolution. You can set the stopwatch – and time the rate of evolution.

The first major breakthrough in this area again came from Iceland. Thanks to the new technology for DNA analysis, a team of Icelandic researchers were able in 2012 to compare parents and children in 78 families. Their comparisons enabled them to confirm a theory that the children of fathers who were older at the time of conception have a higher risk of schizophrenia. The reason for this is that sperm from older fathers contain more mutations. An equally groundbreaking aspect was that the Icelanders were able to quantify the number of new mutations each baby is born with. They average about 30 on the mother's side and about 30 on the

father's side if he is in his thirties. If he is in his sixties, the number of mutations on his side rises to about 60.

Svante Pääbo's team of researchers in Leipzig has attempted to calculate the rate of mutation using a completely different method. They have compared DNA from ancient skeletons with DNA from people alive today. In the past, it was difficult to reconcile the findings from Iceland with estimates of how DNA changes in the course of evolution. The different methods resulted in totally different figures. You could say that the researchers' watches seemed to be ticking at different speeds. But in the autumn of 2014, Pääbo's team published analyses of the DNA of a 45,000-year-old man from a place called Ust'-Ishim in western Siberia. He was the oldest modern human ever subjected to DNA analysis and therefore provided the best benchmark for calibrating the DNA watch.

A degree of uncertainty remains, partly because we do not know exactly how old our forefathers and foremothers were when they had their children. But now the results of the two methods are far better matched. We can assume that each new individual born inherits about 30 new mutations from each parent. If that individual is unlucky, these new mutations can end up in unfavourable locations, where they may be partly responsible for disorders such as schizophrenia and manic depression.

Completely new mutations thus account for part of the risk of contracting one of these psychotic disorders. But there are also many gene variants that are clearly congenital, inherited from parents, maternal and paternal grandparents, and previous generations and lineages. Such gene variants have attached themselves to the human race, even though psychotic disorders bring such huge disadvantages with them. They reduce the chances of survival, and schizophrenia, at any rate, reduces the likelihood of having children of one's own.

The only possible explanation for the continued existence of this inherited trait is that it also confers some advantages. For those who have mental illness in their family, it may be a comfort to reflect that a predisposition to psychosis is

a double-edged thing. Such disorders are undoubtedly disabling; they often place a heavy burden on both the sufferer and on his or her loved ones. Yet they also represent a gift – in the form of creativity and extra energy. These characteristics have been tremendous assets in the course of human history. Indeed, they have actually proven to be indispensable to our development.

That's how I tend to look at it.