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ALMOST HUMAN
Were the Neanderthals our ancestors?

While I was writing this chapter, I made the curious discovery that you can live with someone for years before you notice something about them that is actually quite striking. I suppose it is because they become so familiar that you stop looking *really* closely at them. Then, for some reason, something makes you notice that striking feature, and from then on you can't stop fixating on it.

The other night, I was sitting on the couch next to my husband, Andrew. We were watching television, our dog snoring away happily at our feet, paws twitching as he chased small furry animals in his sleep. A commercial break began and I turned to Andrew to ask him something. It was then that it happened: I noticed that my husband—whom I have known for a large part of my life, and seen virtually every day since I met him—has *enormous* eyebrow ridges.

When I run my hand over my forehead, from my hairline down over my eyebrows, my skull feels smooth, with just the slightest mound of bone pushing outwards at the top of my eye sockets

where my eyebrows are. Andrew's eyebrows, on the other hand, sit on a ridge of bone that juts out over his eyes like an overhanging cliff face. His brow ridges are so large they actually cast shadows over his eyes and, in the right light, down onto his cheeks. I had never noticed these monolithic brows before, but this particular evening followed an entire day spent reading about Neanderthals, that extinct race of human relatives whose place in our evolutionary past is the subject of this chapter.

Neanderthals are the stuff of legend. A pop-culture icon, they are usually depicted—probably quite unfairly—as primitive and brutish cavemen, semi-naked, hairy, with blank expressions, able to communicate with little more than grunts and gestures. Certainly, the name has on several occasions made a convenient insult to throw at members of my family when they display some of their more repulsive behaviours.

But Neanderthals are icons in the scientific world too—for a different reason. The discovery of the first Neanderthal skeleton in 1856 sparked one of the longest-running and most heated debates in modern science, between those who believe the Neanderthals are human ancestors, and those who are adamant that they are merely an extinct side branch of the human evolutionary tree.

Despite many decades of effort, scientists had almost given up hope that the place of Neanderthals in human evolution would ever be known for sure. But then a remarkable piece of ancient DNA research was carried out which would revolutionise the way we view both Neanderthals and our own species.

The reason that my research on Neanderthals led me to notice Andrew's eyebrows was obvious, as there is one particular feature that Neanderthals are famous for—their huge brow ridges. Combine my day's reading with the poor light in our lounge room casting shadows on everything, and Andrew's bony brows didn't

stand a chance of remaining unnoticed. The trouble is, now I can't stop staring at them!

Discovery of the Neanderthal

It was a peaceful late summer day in Germany's Neander Valley in 1856. In the valley was a limestone quarry. For the workers there, the day began as ordinarily as any other. The team had set itself the task of extracting material from two grottoes high on a cliff above the Düssel River, which meanders across the valley floor below. The grottoes were very difficult to reach, both from above and below, and so were the last in the valley to be touched.

The workers began to excavate, but they did not get far before they uncovered a number of bones. There was a skullcap, some thigh bones, ribs, arm and shoulder bones, and part of a pelvis. The workers thought perhaps they were the remains of a cave bear.

Thinking that the bones might be of some interest, they decided to pass them on to the local expert, Carl Fuhlrott. Fuhlrott was a mathematics teacher at the nearby school, but he was also well known in the area for his interest in natural history and his collection of 'curiosities'.

Fuhlrott was struck by the thick, bowed leg bones and the protruding brow ridges on the skullcap, and immediately realised that these were not cave bear bones. He had the radical thought that they might instead belong to a primitive type of human. This was a daring hypothesis, considering the prevailing view of human origins in Europe at the time.

In 1856, when the skeleton was uncovered, European beliefs about human origins stemmed almost entirely from theological tradition. This was in keeping with most other cultures on Earth, which traditionally have a view on human origins that involves

a god or higher being. The Christian church taught that humans were created by God in his own image, just a few thousand years ago. Humans were placed by God at the head of a 'great chain of being', and were followed in this chain by all other 'lower' forms of life on Earth, including animals, plants and insects. Humans were the only creatures believed to have a soul.

Most people at the time did not believe in evolution, the process by which a species or race gradually changes over time into one or more different forms. In fact, church teachings specifically stated that species did not change over time, that they had been exactly the same since they were first created. Most people certainly did not think evolution applied to humans—the very idea was preposterous.

Indeed, there was no compelling reason at the time to believe anything other than church doctrine. Before the unusual skeleton was discovered in the Neander Valley, although a few suspicious-looking fossils had been found, no human ancestor species had actually been recognised. Thus there was no real evidence that humans had ever been anything other than what they are like today, nor was there a solid, scientifically rigorous theory of evolution. Incredibly, the skeleton was uncovered just three years before Charles Darwin published his revolutionary theory of natural selection, which in itself would completely change the way many people thought about the origins of all species on Earth, including humans.

That is not to say that no one had ever thought about evolution before Darwin. Various evolutionary theories had been proposed throughout history, the earliest recorded dating back to the ancient Greeks, some 2500 years ago. However, most of these early evolutionary thoughts were only partially 'scientific', and were interwoven with mythical and religious ideas.

Well before the nineteenth century, science as we know it today began to develop. But evolutionary ideas did not feature in the new discipline of 'natural history', the study of the natural world. Early science was intimately intertwined with religion, and the study of nature was conducted primarily with the purpose of learning more about God's intricate design for the species he had created.

By 1856, the strict religious view was being challenged by some in the scientific world, and the first inklings appeared that species might have changed over time. Evidence for this was the array of fossils being discovered, including enormous dinosaurs and other previously unknown forms of life.

In the years before Darwin published his revolutionary theory, a number of alternative evolutionary theories were suggested. However, each of these had its problems. Some could not be tested scientifically, and others were shown to be false when subjected to scientific testing. Most theories were supported by only a limited number of specialists. The reality was that when the Neander Valley skeleton was discovered, some members of the scientific community were beginning to take the possibility of evolution seriously, but the vast majority of people still strongly followed the religious teachings of creation. Even those who did suspect that some species had changed over time certainly did not believe that humans were in this category.

So when Fuhlrott suggested that a skeleton with such obvious differences to modern-day humans might be some type of human ancestor, and therefore that humans might have changed over time, he showed what a revolutionary thinker he was. Fuhlrott was so intrigued by his idea that he called in Hermann Schaafhausen, a professor of anatomy at the nearby University of Bonn, to give his opinion on the bones. Schaafhausen agreed with Fuhlrott's

suggestion that the skeleton belonged to a primitive type of human. Schaafhausen thought perhaps it came from a race of people ancestral to the Celts and Germans.

Together, Schaafhausen and Fuhlrott presented their hypothesis at a gathering of the Lower Rhine Medical and Natural History Society in Bonn, and with that the great Neanderthal debate began.

The great Neanderthal debate

In light of the accepted view of human origins at the time, it is not surprising that the skeleton, with its unusual features, and Schaafhausen and Fuhlrott's assessment of it, caused quite a stir.

The skeleton burst into a scientific world already divided over evolutionary matters, and at first only helped to emphasise the differences of opinion. There was no reliable method available at the time to determine how old the bones actually were, so it was really anyone's guess what the skeleton was.

On the one hand, those who already had leanings towards evolutionary ideas believed that the skeleton was of great antiquity, and eagerly agreed that what had been found was the first evidence that humans had changed through time—in other words, evolved—just as they believed other species had done. Others were not so convinced. They thought that the skeleton was fairly recent in origin, and had belonged to an individual who had suffered from a variety of physical deformities throughout his or her lifetime, perhaps due to a severe disease such as rickets.

One of the more amusing suggestions put forward at the time was that the bones had belonged to a Russian Cossack, who had died when sheltering in the cave from an approaching army. He had bowed legs because he had spent years riding horses, and his

huge brow ridges were due to his constantly furrowed brow, his reaction to intense stress. How exactly he had come to shelter in a cave some 18 metres up a cliff face, stark naked and without his weaponry, was never explained.

Hoping to end the argument once and for all, Rudolf Virchow, a German anatomist and pathologist, conducted a thorough analysis of the bones. Virchow was a prominent figure in German science, but he happened to have an intense dislike of the idea of evolution. It is perhaps not surprising that he concluded that the skeleton was not ancient after all. Instead, he professed, the appearance of the bones was indeed due to some form of illness. He suggested, like others before him, that the person the skeleton belonged to had suffered from rickets as a child, which explained the bowed legs. The large brow ridges, he concluded, were caused by repeated blows to the head.

As a result of Virchow's analysis, most experts at the time initially came to agree that the enticing view into our evolutionary past offered by the skeleton was imaginary—the skeleton was nothing more than that of a fairly recently deceased unfortunate, who must have endured a life of great pain and suffering.

This might explain one odd-looking skeleton, but it wasn't long before fossil enthusiasts began to uncover skeletons with the same unusual characteristics from a whole range of sites scattered throughout Europe and Western Asia—and to reassess a couple of earlier discoveries. Some were found with stone tools and the remains of extinct animals, the first hard evidence that the skeletons themselves might indeed be ancient.

The idea that the large brow ridges and heavy, bowed limbs, now seen time and time again, could be due to disease began to seem extremely unlikely. Whoever they were, it became obvious that these strange beings had been a significant population at some

time in the history of that region of the world. They were even given a name, 'Neanderthals', after the Neander Valley where the first identified skeleton was found.

In 1859 the Neanderthal cause was strengthened by the publication of Darwin's famous book, *The Origin of Species*, in which he outlined his groundbreaking evolutionary theory of natural selection. Perhaps unsurprisingly, Darwin's 'heretical' ideas immediately met with fierce opposition, especially amongst the religious community. However, he also had some influential supporters. The result was a series of fierce debates, and evolution became a very popular topic for discussion in society. The ultimate outcome was that, although the idea of evolution remained anathema to many, a much larger percentage of the population began to accept the possibility that not only plants and animals, but humans too, evolved.

Nineteenth-century Neanderthal experts still thought of their subjects as primitive and brutish cavemen, quite inferior in all aspects to modern-day humans. But in the light of overwhelming evidence, they were soon forced to agree that Neanderthals were indeed a significant race of people who had some place in human prehistory. Many questions remained unanswered, however. Where did they come from? Why did they suddenly disappear? Could they have been the direct ancestors of modern-day Europeans? Or were they simply a side-branch in the human evolutionary tree, a race doomed to extinction?

Intriguing questions indeed, and a large number of people became determined to find answers. As the realisation began to dawn that humans really *had* evolved, hunting for fossilised human ancestors became extremely fashionable, and a virtual digging frenzy ensued. The secrets of humanity's past, hidden for so long inside the Earth, were about to be revealed.

More discoveries: Homo erectus

Fossicking for fossils began in earnest and more Neanderthal remains were soon uncovered, adding to the growing wealth of knowledge about this intriguing race. But even more interestingly, fossil hunters began to find remains from a range of other previously unknown human ancestors. It soon became obvious that humans as a species had a rich and complex family tree. All over the world, the scattered pieces in the jigsaw of human evolution began to emerge.

The very next human ancestor to be discovered turned out to be an important player in the Neanderthal drama. Eugene Dubois, a Dutch scientist and evolutionary enthusiast, began an expedition in the 1890s to search for human ancestors in Indonesia. His rationale for searching in this part of the world was that chimpanzee and orang-utan fossils had recently been found there. As these apes are the closest living relatives to humans, Dubois thought, logically, human ancestor fossils must also be located there.

As it happens, he was correct. After excavating at several sites with no success, Dubois and his team finally uncovered some quite remarkable fossils on the banks of the Solo River in Java: skeletal remains that were similar to Neanderthals, with the same brow ridges and robust skeletal features, but with a noticeably smaller brain. An even older human relative had been found. The new ancestor was named *Homo erectus*, or 'Upright Man', and more fossils, similar to the ones in Java, were soon found in many other regions of the world.

Apart from being an interesting human ancestor in its own right, *Homo erectus* is particularly important to this story because it turned out to be the key to the *origin* of the Neanderthals. Based on the fossil evidence, it is believed that *Homo erectus* evolved in Africa

from another even older human ancestor, at least 1.5 million years ago. Just like modern-day humans, *Homo erectus* became a very effective coloniser and eventually moved out of Africa, to spread throughout Asia, the Middle East, India and Europe. As it turned out, *Homo erectus* was the earliest human relative ever to travel about the world. All previous human ancestors—and there were quite a few before *Homo erectus* appeared—had been confined to the African continent.

As time went on, researchers realised that the *Homo erectus* remains found in different parts of the world exhibited slightly different skeletal features. These were much like the small variations that can be seen in people all over the world today, but it was even more pronounced in the various races of *Homo erectus*. These 'racial' differences make some researchers think that the races of *Homo erectus* were so different that they could have even been separate species, unlike modern-day humans, who are all members of the one species, *Homo sapiens*.

And here is the key to the origin of the Neanderthals. The fossils that have been found clearly show that they evolved around 300 000 years ago as descendants of one of the races of *Homo erectus* that lived in Europe and the Middle East. Exactly which race gave rise to the Neanderthals is still debated, but essentially the discovery of *Homo erectus* solved one part of the Neanderthal mystery—the mystery of where they came from.

Neanderthal lifestyle and culture

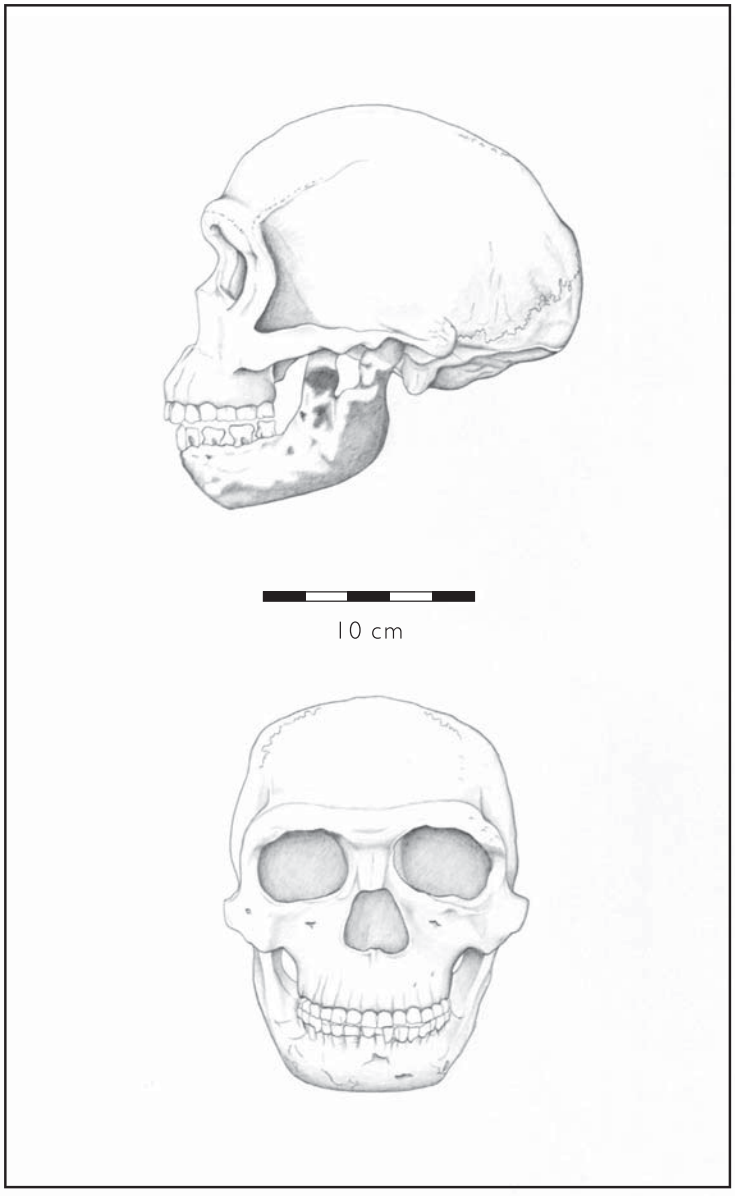
Along with this insight into their origins, a detailed picture also began to emerge about the Neanderthal lifestyle: when and where they lived, as well as a glimpse of what their personalities might have been like.

We now know that the Neanderthals were a race of prehistoric people who lived in an area stretching right across Europe and Western Asia as well as in parts of the Middle East. They first appeared from a race descended from *Homo erectus* as long as 300 000 years ago. For thousands of years they lived in this part of the world, but around 30 000 years ago they disappeared forever.

Neanderthals are usually portrayed as brutish, primitive, rude and vulgar, with huge muscles, terrible manners and very low intelligence. They are often shown in a stooped posture, almost as if they are too stupid to drag themselves into a fully upright position. This is certainly what the first people to discover them thought, and this perception of the Neanderthals has persisted, helped along by cartoons, books and general opinion. But were they really like this?

It is true that Neanderthals were extremely strong: although they were somewhat shorter than humans, they were stocky, with large muscles. In particular, they had huge jaw muscles, and must have had an enormous bite strength. In fact, the major way in which Neanderthals differed in appearance from modern humans was in the skull. Neanderthals had large faces, low foreheads and huge brow ridges. If you feel your own chin, you will find a bony piece poking out at the bottom of your jaw. Neanderthals did not have this, which is why their chins appeared to recede.

It is not true, however, that they had a stooped posture. That particular myth is the result of an unfortunate coincidence. It just so happened that the first Neanderthal skeleton to be examined in detail was, although researchers didn't know it at the time, from an individual who had suffered a debilitating disease during his or her lifetime which resulted in a stooped appearance. With no basis for comparison, researchers assumed that all Neanderthals were



like that, and even when more skeletons which were clearly not stooped were found, the myth persisted.

There is also no real evidence that Neanderthals were mentally inferior to modern-day humans. In fact, Neanderthal brains were slightly larger than ours. There is no way of knowing for sure how Neanderthal thought processes worked, but the assumption that they were 'a couple of sandwiches short of a picnic' probably reflected the fact that nineteenth-century Europeans generally believed *anyone* different from them must be inferior. Again, this view of Neanderthals has persisted.

Neanderthal tools were relatively simple, and Neanderthals did not make intricate ornaments, cave paintings or jewellery, as prehistoric humans did. This has always been taken as further evidence of the inferior Neanderthal brain. But it was recently discovered that the earliest humans, with brains every bit as developed as ours, did none of these things either. It wasn't until humans had been around for quite a while that these aspects of culture started to develop. The Neanderthals' simple tools and lack of art, once considered a sign of inferior brain power, can therefore no longer be thought of in this way.

Neanderthals had one other trait which is usually considered to be uniquely human. There is evidence that they buried their dead, something no animal apart from humans is known to have done. This indicates that Neanderthals might actually have cared deeply for one another, which is far from the traditional view of how they might have behaved.

Opposite: *A Neanderthal skull, showing the characteristic brow ridges and lack of a chin. Compared with a modern human, the skull is longer from back to front, and rounder at the sides. The average size of the Neanderthal brain was slightly larger than that of a human.*

What became of the Neanderthals?

Unravelling the mystery of the origin of the Neanderthals, and learning more about their lifestyle, personality and distribution, proved to be interesting and fruitful areas of scientific research. However reaching a consensus as to what *became* of the Neanderthals turned out to be much more difficult and controversial. Were they indeed the direct ancestors of modern Europeans, as Fuhlrott and Schaafhausen had first suggested? Did they therefore disappear from the fossil record simply because they evolved into humans? Or were they distant cousins who became extinct without leaving any descendants?

It soon became apparent that these seemingly simple questions would be extremely problematic to answer; from the beginning, ideas about the fate of the Neanderthals were continually tossed back and forth on a tide of controversy. The fate of the Neanderthals turned into one of the longest-running and most heated scientific debates in history.

As time passed, a variety of fads came and went: one minute Neanderthals were hailed as the ancestors of humanity and the next they were shoved aside as merely an extinct cousin, a withered branch to nowhere on the family tree. Try as they might, researchers could not come to an agreement on the fate of the Neanderthals, or on their relationship to modern-day humans. Over the decades that followed, new discoveries and new methods of analysis were developed, but often these only added to the debate. The trouble was that the available evidence was just too ambiguous.

By the mid-1980s, after almost 150 years of intense research and debate, the issue of the Neanderthals' fate was no closer to resolution. Two fiercely opposing sides had formed in the argument, one believing the Neanderthals to be human ancestors, the other adamant they were not.

More arguments over fossils

By this stage, researchers had at their disposal not only an abundance of fossils, but also a variety of innovative new dating methods —tools that would have been unimaginable to the earliest Neanderthal enthusiasts. Despite this, the two groups of researchers were as directly and fiercely opposed to each other's theories as earlier generations had been, for both sides could see plenty of evidence in the fossil record to support *their* side of the argument.

At the forefront of one side of the modern-day Neanderthal debate was Chris Stringer, a palaeontologist from the Natural History Museum in London. Stringer and his supporters strongly believed that the fossil evidence indicated that Neanderthals could not possibly have been direct human ancestors.

The group proposed a scheme for the fate of Neanderthals which became known as the 'Out of Africa' hypothesis. The hypothesis began with the time just before modern humans evolved, when Earth was populated by the various races descended from *Homo erectus*. Neanderthals, of course, were one of these races. According to Stringer's scheme, each race had evolved to the point where it was distinctly different from all the others—so different, in fact, that each was actually a separate species.

Stringer and his colleagues proposed that modern humans then evolved *in Africa only*, springing as a new species from just one descendant species of *Homo erectus* that had existed there. Over the tens of thousands of years that followed, modern humans then spread throughout the rest of the world, replacing all the other descendants of *Homo erectus*, including Neanderthals. Because they were separate species, no interbreeding could occur between the invading humans and the other *Homo erectus* descendants, meaning that Neanderthals, and any other descendants of *Homo erectus* outside Africa, are in no way the ancestors of humans.

How the proposed takeover might have happened is not entirely clear. However, it is possible that the earlier humans might have fought and killed all the races of *Homo erectus*. Alternatively, they might simply have out-competed them for food and resources. Unfortunately, this theory has a dismal end for the Neanderthals—they simply became extinct.

Stringer and his colleagues believed that the fossil record supported their theory entirely, showing an abrupt difference between the skeletons of the various races of *Homo erectus* and the skeleton of a modern human, thereby proving that it was not possible for *Homo erectus* to have evolved into modern humans in most regions in the world. The one exception to this, Stringer said, was in Africa, where the *Homo erectus* fossils did show a smooth transition to modern humans, in perfect agreement with their theory.

In stark opposition to Stringer and his colleagues was the group led by Milford Wolpoff, a palaeoanthropologist from the University of Michigan. Wolpoff and his colleagues believed quite strongly that Neanderthals *were* one of humanity's ancestors—and that they had evidence to prove it.

Wolpoff's theory also began just before humans evolved, when Earth was populated with the various races descended from *Homo erectus*, including Neanderthals. However, in complete contrast to Stringer, Wolpoff and his colleagues believed that all the different races of *Homo erectus*, although subtly different from each other, *were* still members of the same species, and were therefore able to interbreed freely.

Over many thousands of years, or so this theory goes, the different races of *Homo erectus* continued to evolve, changing ever so slightly, but never losing their ability to interbreed. Eventually, thousands of years ago, they became what we would consider to be human. Humans did not evolve only in Africa, from one *Homo*

erectus descendant, said Wolpoff, but from a mixture of *Homo erectus* descendants all over the world.

According to this model, Neanderthals have an important place in human evolution as one of humanity's ancestors, together with a number of other races of *Homo erectus*. Wolpoff and his supporters believed that each human race is descended primarily from a slightly different race of *Homo erectus*, and this is the cause of the racial differences that can be seen amongst humans today. This would mean the differences that exist between the various human races are very old, dating back a million years or more to when *Homo erectus* first began to split into different races. For obvious reasons, this theory became known as the 'Multiregional Evolution' hypothesis.

Like Stringer, Wolpoff and his colleagues found support for their theory in the fossil record. It was all a matter of how the fossils were interpreted. Wolpoff did not agree with Stringer's belief that *Homo erectus* fossils outside Africa were starkly different from modern human fossils. He believed that Neanderthal and other human ancestor fossils over the past 1.5 million years or so showed a gradual transition from *Homo erectus* to modern humans all over the world. For example, he believed that modern-day Asians closely resemble the *Homo erectus* fossils found in that region, and that modern-day Europeans resemble Neanderthal fossils. From Wolpoff and his colleagues' point of view, the fossils confirmed that Neanderthals, along with the other *Homo erectus* races, can be considered the ancestors of humans.

Based on fossil evidence alone, an impasse had again been reached in the debate about the fate of the Neanderthals, and was proving very hard to resolve. After almost 150 years of debate, and still no agreement, it seemed that the issue would never—in fact, *could* never—be solved.

Human DNA extraction and its implications

In 1987, the issue of the fate of the Neanderthals and their relationship to humans took another rather exciting twist when some completely new evidence was supplied—evidence which, for the first time, did not rely on the troublesome human fossil record. In a remarkable announcement in the prestigious scientific journal *Nature*, Berkeley researchers Rebecca Cann, Mark Stoneking and Allan Wilson presented an innovative and clever method to investigate the question of human evolution in a completely new way: by looking for clues in DNA extracted directly from people alive today.

Carefully and painstakingly, the researchers had collected tissue samples from 147 modern-day people who originated from a range of different geographical locations, including Africa, Asia, Australia, Europe and Papua New Guinea. Using the same basic process described in the Introduction, the scientists extracted DNA from each sample, then compared specific sections of the DNA. What they found was the startling fact that all humans, whether from Asia, Africa or Europe, or anywhere else for that matter, have astonishingly *similar* DNA. This simple finding may seem rather trivial on the surface, but in fact it had great implications not only for the debate about the fate of Neanderthals, but for the origins of humanity itself.

To make sense of what Cann, Stoneking and Wilson's research indicated, I like to think of a story that my mother often tells about the day I was born. Having first established that I was a girl and that I was well and truly alive, my mother 'gave me the once over' to see what I looked like. As a result of this understandable curiosity, one of the first sentences to fall on my ears was: 'Oh my God! She has her grandpa's toes!'

The point of this story? That from the moment we are born, it is

obvious just how closely each of us resembles our nearest relatives. The same is also true of DNA, the genetic material inside each and every cell which determines many aspects of what we look like and how we behave—in essence, who we are. DNA is passed on from parents to offspring and ancestor to descendant but, over time, mutations, or changes, tend to occur in the DNA. The result is that the more closely related two living things are to each other, the more similar their DNA is likely to be. It follows, therefore, that if two living things have very similar DNA, it is a pretty sure bet that they are close relatives, and shared a common ancestor quite recently.

Cann, Stoneking and Wilson's research showed that all humans have remarkably similar DNA—the section they looked at differed by an average of only about 0.5 per cent amongst all the 147 people they sampled. This implied that modern-day humans are all very closely related, and are therefore likely to have had a very recent common ancestor.

As if this result alone were not enough, Cann, Stoneking and Wilson then performed a clever piece of mathematical analysis to calculate when and where this common ancestor of all humans is likely to have lived. The method they used is actually quite straightforward: previous analysis of human and animal DNA had indicated that, due to the naturally occurring mutations that are a feature of the DNA of all living things, the section of DNA they had focused on tends to evolve (change) at a rate of 2–4 per cent per million years. The fact that all the DNA in their samples differed by an average of about 0.5 per cent indicated that the common ancestor of all humans probably lived somewhere in the region of 140 000–290 000 years ago. Furthermore, because of the patterns of similarities and differences between the DNA in their samples, the researchers were able to postulate that this ancestor lived in Africa.

On the face of it, this DNA evidence seemed squarely to defeat Wolpoff and his supporters' view. Their theory stated that humans had arisen in multiple regions of the world, from multiple *Homo erectus* descendants, one of which was the Neanderthals. This implied that the common ancestor of humans was much older—dating back to early *Homo erectus* times, which could be as long ago as 2 million years or so. If this were the case, DNA from modern-day humans should be much more diverse, as there would have been much more time for mutations to occur.

The view of Stringer and his colleagues, on the other hand, matched perfectly with the results of Cann, Stoneking and Wilson's DNA work. The Out of Africa hypothesis said that humans evolved recently in Africa only, and were descended from just one, non-Neanderthal race of *Homo erectus*—exactly what Cann, Stoneking and Wilson's results indicated.

Did this mean that the Neanderthal debate was over at last? Unfortunately, not quite. Wolpoff would not accept the results of the DNA work for a moment, and certainly was not going to be silenced easily. Stating that 'there isn't a snowball's chance in hell' that Cann, Stoneking and Wilson were correct, he insisted that the fossils do not lie—that they clearly show a transition from *Homo erectus* to humans everywhere in the world that one would care to look—and that no modern human DNA would change this. 'If you really want to know where modern humans come from, go look at some fossils,' he said defiantly.

As well as his unwavering faith in what the fossils seemed to be telling him, Wolpoff also questioned some of the methods of analysis the researchers had used in their study, and reiterated his belief that the results did not accurately reflect what really happened when humans evolved. His supporters agreed with him. So the debate continued.

Neanderthal DNA enters the scene

An impasse had again been reached. The difficulty was that comparing DNA from modern-day humans, although innovative, was an indirect method of looking at the past. There would always be questions of interpretation, and debate over whether modern-day DNA really can accurately reflect past events.

The DNA evidence did seem to support the Out of Africa hypothesis that Neanderthals could not have been human ancestors, but it was clear that some more direct evidence was needed if the debate were to be solved once and for all.

It wasn't long before researchers took the next logical step. What if it were possible to extract DNA directly from a Neanderthal bone, and compare it to DNA from modern-day humans? If Neanderthals really were the direct ancestors of humans, in particular those people still residing in the areas where Neanderthals had lived (which included Europe and Western Asia), they would have passed their DNA directly on to their modern human descendants, and it should be quite similar to the DNA of modern-day Europeans and Western Asians.

On the other hand, if Neanderthals were *not* the direct ancestors of Europeans, but only a more distant relative, Neanderthal DNA should be quite different to that of modern Europeans. If Neanderthal DNA could be extracted and analysed, perhaps the debate could finally be resolved.

No one could have been in any doubt that the task of extracting and analysing Neanderthal DNA would be one of the most challenging ancient DNA projects ever attempted. So Neanderthal researchers decided to approach one of the pioneers of ancient DNA research, Svante Pääbo, from the Zoological Institute at the University of Munich, Germany.

Born in Sweden, Pääbo had studied archaeology at university level while still at high school, but found the work 'too slow' and turned to the study of immunology. Then, while a graduate student, he began to dabble in the brand-new field of ancient DNA research in his spare time. After some convincing, the director of an East Berlin museum allowed Pääbo to experiment on the museum's Egyptian mummy collection, and he began trying to extract DNA from the ancient remains at night and on weekends.

Pääbo obviously found his niche with ancient DNA, and continued to develop this emerging field of research, first at the University of California, Berkeley, and then at the Zoological Institute of the University of Munich. By the time the Neanderthal DNA work began, he had made quite a name for himself, and was the perfect person to take charge of such a difficult task.

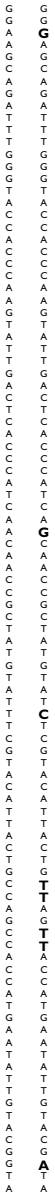
Together with his graduate student Matthias Krings, Pääbo removed a tiny 3.5 g sample of bone from the right humerus of a Neanderthal. Fittingly, the bone was from the original skeleton found in 1856 in the Neander Valley. Painstakingly, the pair extracted the DNA from the sample, using the same basic process described previously. Next, they compared sections of the Neanderthal DNA with the equivalent sections of DNA from a number of present-day human samples, from people from different regions of the world.

A DNA strand is a long, thread-like molecule, made up of a string of smaller units, called 'bases', which are linked together to form the strand. There are four different types of bases: adenine (written as A), thymine (T), guanine (G) and cytosine (C). In the cells of organisms, two strands of DNA are wound together to form the famous 'double helix', which is in turn wound and bundled further to form the shape of the chromosomes (see diagram, p. 3).

In order to compare the DNA in two different organisms, as I mentioned earlier, DNA is first extracted from samples of each,

and copies are made in the laboratory of the particular segment of DNA from each sample that researchers are interested in. The next step is to determine the DNA sequence—the order of bases in the DNA strand—from that particular sample. This is done in a process that uses a variety of chemicals and enzymes, and which these days is often performed in an automated fashion by large machines known as DNA sequencers. Once the DNA sequences of each sample are known, they can be compared and analysed. At this stage, it is more or less a matter of simply lining up the sequences on a computer screen and looking for similarities and differences.

When Pääbo and Krings lined up their sequence of Neanderthal DNA with the sequence from the equivalent section of modern human DNA, there was no mistaking the results. Neanderthal DNA and human DNA were quite different. To be exact, Pääbo and Krings found the Neanderthal DNA varied from human DNA sequences by an average of 26 individual differences. To be sure the results were correct, researchers Anne Stone and Mark Stoneking repeated each step of the procedure at an independent laboratory at the Department of Anthropology of Pennsylvania State University. The DNA they extracted was exactly the same, which confirmed Pääbo and Krings' results.



*Section of human (left) and Neanderthal (right) DNA sequences. Differences are shown in bold in the Neanderthal sequence. Only one strand from each DNA double helix is shown—the other can be inferred using the base pairing rule (*A *pairs with* T*, and* C *pairs with* G*). (This diagram is adapted from the sequence shown in Krings, M. et al (1997), 'Neanderthal DNA sequences and the origin of modern humans',* Cell*, vol. 90, pp. 19–30)*

A conclusion to the Neanderthal debate at last?

There was only one conclusion that Pääbo and his team could make. If Neanderthals truly were human ancestors, their DNA would have been much more similar to modern human DNA. Instead, their work provided the first truly clear evidence that Neanderthals could not possibly have been human ancestors.

As soon as the results of the Neanderthal DNA work were announced, debate erupted again with a vengeance. Everyone had something to say about what they thought of the results, and what it meant for the Neanderthals. Was this finally absolute proof that Stringer and his colleagues were right, and that Wolpoff and his colleagues were wrong? Was the great Neanderthal debate finally over?

Stringer and his colleagues were understandably delighted with the results of the experiments. Stringer called the DNA work 'a terrific achievement', one which, in his opinion, provided compelling evidence that he and his supporters had been correct.

Not so fast, said Wolpoff and his supporters. Although agreeing that the Neanderthal DNA was 'an extremely important piece of work', Wolpoff pointed out that there was only one sample of Neanderthal DNA so far, and more would be needed before any definite conclusions could be drawn. Some other aspects of the analysis of the Neanderthal DNA bothered him too. 'It's not that I want to rain on anybody's parade,' he said, 'but there are some nagging details.'

Although no one could deny that a truly revolutionary piece of work had been carried out, it became apparent that a single Neanderthal DNA sample was not going to end the debate. More Neanderthal DNA, from a different individual, needed to be extracted and compared with Pääbo's results.

Thus it was that a short time later, a second team of scientists, led by researcher Igor Ovchinnikov, extracted DNA from a second Neanderthal specimen, a child found in a cave in southern Russia, one of the easternmost Neanderthal populations. Despite the geographic separation between the samples, when the DNA of the Russian Neanderthal was compared with the DNA from the first Neanderthal, it proved to be very similar. Like the DNA from the first Neanderthal, the Russian Neanderthal DNA was also very different to the DNA of modern humans.

Krings, Pääbo and their colleagues also extracted DNA from Neanderthal bones found in a cave in Croatia. Again, the DNA was similar to the previous two samples, and quite different to that of modern humans.

Three Neanderthal DNA samples now showed that Neanderthal DNA was significantly different to modern human DNA. Despite this evidence, Wolpoff and other Multiregional Evolution hypothesis supporters still did not accept that it had been conclusively proven that Neanderthals were not human ancestors. They pointed out a fundamental flaw in the research—that Neanderthal DNA was being compared with DNA from *present-day* humans, not DNA from humans living several thousand years ago, closer to the time that the Neanderthals had disappeared. What if, Wolpoff suggested, human DNA has changed since that time? If this was the case, then maybe DNA from early true humans would be much more similar to Neanderthal DNA, meaning they could be human ancestors after all.

Wolpoff had a good point, researchers on both sides of the debate agreed—until there was a good picture of not only what Neanderthal DNA was like, but also the DNA from the earliest true humans, we wouldn't know for certain. Extracting and comparing ancient human DNA and Neanderthal DNA would help to clear up

any nagging doubts created by comparing modern human DNA with ancient Neanderthal DNA.

This led to a group of Italian and Spanish scientists extracting DNA from a sample of bone from a 25 000-year-old fully modern European human from the Paglicci cave in southern Italy. Pieces of DNA from this skeleton were compared with DNA from present-day people and to Neanderthal DNA. The DNA showed just what Stringer and his supporters had suspected: the DNA from the ancient modern human matched present-day human DNA but did not match Neanderthal DNA. This, surely, makes it extremely unlikely that the Neanderthals were human ancestors.

Conclusion: Neanderthals are not human ancestors

In a stunning example of the power of ancient DNA research to provide answers to fascinating real-life issues, the Neanderthal DNA work has finally made it possible, after 150 years of debate, to say with some certainty that the enigmatic Neanderthals are not the ancestors of humans, but are simply an example of an extinct species, albeit an extremely interesting one.

As we are all too aware, species extinction has been an ongoing natural phenomenon throughout the evolutionary history of life on Earth. Some estimates suggest that as many as 99 per cent of all species that have ever lived are now extinct.

A T C G

Although species become extinct, they do not always vanish without a trace. Sometimes, by lucky coincidence, when an organism dies its remains become preserved. Because of this, it has been possible to find the bones, teeth, fossils and sometimes entire preserved carcasses of extinct species.

Some of these remains still contain DNA. Research on the DNA from extinct species is in fact one of the most productive areas of ancient DNA work and, just as in the case of the Neanderthals, is regularly used to investigate the relationships between extinct species and their living relatives.

While this is an interesting and productive area of research in itself, it has paved the way for exploration of an even more intriguing proposition: whether DNA could be used to bring an extinct species back to life. Might we one day create a 'prehistoric zoo' in which monkeys mix with mammoths, and tigers with thylacines? Does extinction have to mean forever?