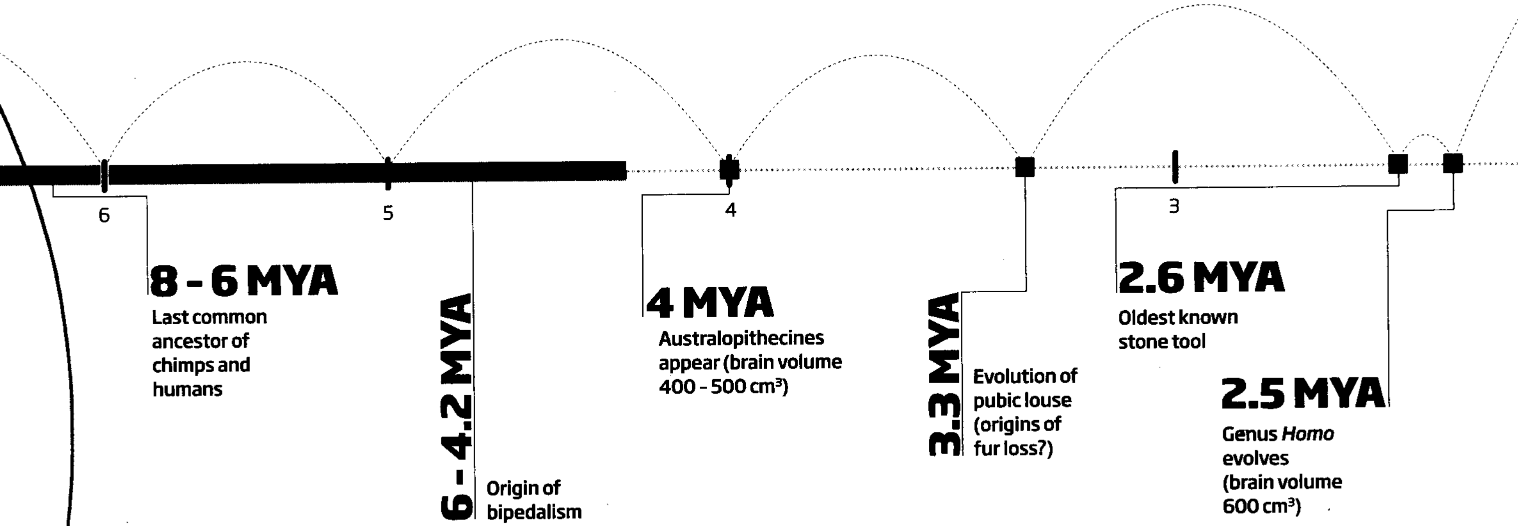
RIDDLES OF OUR PAST

Much has been learned, yet the human story is still full of mysteries. *New Scientist* goes in search of the biggest



Why are we so different from chimps?

NOBODY would mistake a human for a chimpanzee, yet we share more DNA than mice and rats do. How can that be? Advances in genomics are starting to unravel the mystery.

Line up the genomes of humans and chimps side by side and they differ by little more than 1 per cent. That may not seem like much, but it equates to more than 30 million point mutations. Around 80 per cent of our 30,000 genes are affected, and although most have just one or two changes (*Gene*, vol 346, p 215), these can have dramatic effects. The protein made by the human gene *FOXP2*, which helps us to speak, differs from its chimp counterpart by just two amino acids, for example. And small changes in the *microcephalin* and *ASPM* genes may underlie big differences in brain size between humans and chimps.

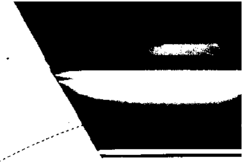
But protein evolution is only part of what makes us human. Also critical are changes in gene regulation – when and where genes are expressed during development – says James Noonan of Yale University. Mutations in key developmental genes are likely to be fatal. But, he says: "Altering the expression of a gene in a single tissue or at a single time can more easily lead to an innovation that is not lethal." Noonan's lab is one of many that are busy comparing gene expression in tissues such as the brain to home in on the key regulatory difference between chimps and humans, most of which have still to be uncovered.

Then there's gene duplication. This can give rise to families of genes that diversify and take on new functions, says Evan Eichler at Washington State University in Seattle. His lab has identified uniquely human gene families that affect many aspects of our biology, from the immune system to brain development. He suspects that gene duplication has contributed to the evolution of novel cognitive capacities in humans, but at a cost: greater susceptibility to neurological disorders.

Copying errors mean whole chunks of DNA have been accidentally deleted. Other chunks find themselves in new locations when mobile genetic elements jump around the genome or viruses integrate themselves into our DNA. The human genome contains more than 26,000 of these so-called INDELs, many linked with differences in gene expression between humans and chimps (*Mobile DNA*, vol 2, p 13).

Even a complete catalogue of genetic differences will not solve the mystery. Much of what makes us human is cultural, passed from generation to generation by learning, says Ajit Varki at the University of California, San Diego. What's more, he says, The co-evolution of genes and culture is a major force in human evolution, famously leaving the descendents of dairy farmers able to digest milk protein, for example. To crack the mystery of human uniqueness we need to know how genomes build bodies and brains, how brains create culture, and how culture eventually feeds back to alter the genome. It remains a distant goal. Dan Jones

TIM WATKINS



Why did we become bipedal?

CHARLES DARWIN suggested that our ancestors first stood upright to free their hands for toolmaking. We now know that cannot be right since the oldest tools yet discovered are a mere 2.6 million years old, whereas the anatomy of hominin fossils reveals that bipedalism emerged at least 4.2 million – and possibly even 6 million – years ago.

The trouble with bipedalism, says Chris Stringer at the Natural History Museum in London, is that proficient walking has many advantages, but acquiring the skill requires anatomical changes, and in the meantime you will be slow, clumsy and unstable. "It could have begun in the trees," he suggests, pointing out that orang-utans and other primates walk upright along branches when feeding. This fits with what we know about the lifestyle of the first bipeds but does not explain why they evolved specialist anatomy. By 4 million years ago, for instance, the tibia in the lower leg was held upright to the foot, whereas it is angled to the outside in apes living now, even those that spend the most time on two legs.

In a more compelling evolutionary explanation bipedalism would substantially boost survival, which is why some people believe it evolved to allow males to access more food so that they could help feed their partners and offspring (*Odyssey*, vol 2, p 12). But this idea presupposes a very early origin of monogamy, which the evidence doesn't support, says Donald Johanson of Arizona State University in Tempe, who in 1974 discovered Lucy, a 3.2-million-year-old, upright Australopithecine. He points out that among early hominins, males were much larger than females, which in primates is a sign that there is competition rather than cooperation between the sexes.

"The real question is what were the benefits," says Johanson. One possibility is that individuals who could wander further than others had access to a wider variety of food sources, allowing them to live longer and produce more surviving offspring. In addition, bipedalism would have left their hands free to carry things and, being taller, they may have been better at spotting predators. "There might have been a whole package of advantages," he says, adding that bipedalism may have emerged more than once.

All of which would have set the stage for a second phase of evolution around 1.7 million years ago, when our ancestors left the forests for the savannah. This is when the greatest anatomical changes took place, with shoulders pulled back, legs

2

1 million

2 MYA ***Homo erectus*** **evolves (brain volume 850 cm³)**

1.8 MYA ***Homo erectus*** **leaves Africa for Asia (brain volume 1000 cm³)**

1.7 MYA **Savannah living established**

1.6 MYA **Pleistocene ice age begins**

First use of fire?

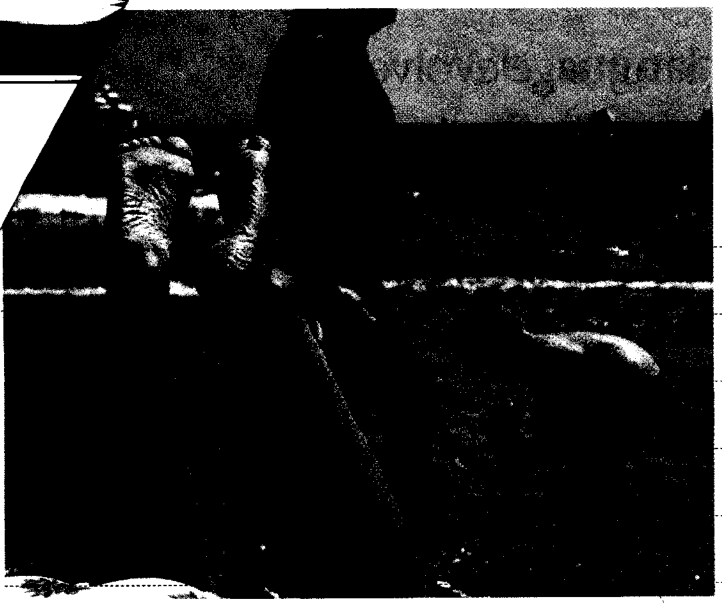
Stone hand axes are a technology that took more than 2 million years to perfect

THE NATURAL HISTORY MUSEUM/ALAMY

Why was technological development so slow?

SHARP stone flakes found two decades ago in a parched riverbed in the Afar region of Ethiopia are the oldest tools yet discovered. They date from 2.6 million years ago. It would be another million years before our ancestors made their next technological breakthrough. Then, instead of using the chips off a river cobble as blades and scrapers, someone realised that the cobble itself could be worked into a tool. "It is recognisable as a hand axe, but very rough," says Dietrich Stout of Emory University, Atlanta. Another million years passed before early modern humans perfected this technique. What took them so long?

Intelligence must have played a part. In the 2 million years after the appearance of the first tools, hominin brain size more than doubled, to around 900 cubic centimetres. Toolmaking undoubtedly requires smarts, and Stout has used MRI scans of people knapping stones to find out which brain areas are involved. The studies suggest that early technological innovations depended on novel perceptual-motor capabilities – such as the ability to control joint stiffness – while later developments were underpinned by growing cognitive complexity, including the sort of recursive thinking required for language (*PLoS One*, vol 5, e13718). So, although tools appear not to develop much, their production is underpinned by great cognitive advance, leading Stout to conclude that there was more progress during this period than we tend to think. What's more, he says, people may have made other tools from materials such as



MARTIN PARR/MAGNUM

Walking upright boosts mobility and decreases exposure to the sun

lengthened and a pelvis adapted to life on two legs.

There are many possible reasons why bipedalism took off at this point. Walking upright might have helped individuals deal with the scorching heat of the open grassland, allowing air to circulate around the body while minimising direct exposure to the sun (*Journal of Human Evolution*, vol 13, p 91). It would also have increased mobility. "I think the argument comes down to travel efficiency and travel distance," says Robin Dunbar at the University of Oxford. Bipedalism allowed our ancestors to walk long distances, enabling them to track down prey on the savannah. One study even suggests that we become adapted for endurance running (*Nature*, vol 432, p 345), although modern couch potatoes may consider this idea a step too far. **Kate Douglas**

900,000 | 800,000 | 700,000 | 600,000 | 500,000 | 400,000

600,000 YA

Homo heidelbergensis **capable of speech (brain volume 1200 cm³)**

500,000 YA

Sophisticated hand axes

wood and bone that perished long ago.

"Even allowing for that, stone-tool progress looks painfully slow," says Chris Stringer of the Natural History Museum in London. In his book *The Origin of Our Species* (Allen Lane, 2011) he identifies another reason – demography. "It's not what you know, it's who you know," he says. Modern humans have large populations with lots of people copying and many ways to pass on information. Our long lives also permit transfer of ideas down the generations, whereas *Homo erectus* and *Homo heidelbergensis* probably had a maximum lifespan of around 30 years, and Neanderthals maybe 40. "They're having to grow up very fast and there's much less networking between groups," Stringer says.

Furthermore, our ancestors may have shunned change since life would have been challenging enough without risky experimentation. "It's dangerous to go around innovating and inventing," says Stringer. Mark Pagel at the University of Reading, UK, doubts that hominins before *Homo sapiens* had what it takes to innovate and exchange ideas, even if they wanted to. He draws a comparison with chimps, which can make crude stone tools but lack technological progress. They mostly learn by trial and error, he says, whereas we learn by watching each other, and we know when something is worth copying. If Pagel is correct, then social learning is the spark that ignited a technological revolution (*Wired for Culture*, Penguin, 2011). "With the arrival of modern humans the game changed," he says. **Kate Douglas**

98.5%

DNA shared by chimps and humans

When did language evolve?

15W

Energy consumption of a human brain

WITHOUT language we would struggle to exchange ideas or influence other people's behaviour. Human society as we know it could not exist. The origin of this singular skill was a turning point in our history, yet the timing is extremely difficult to pin down.

We do know that *Homo sapiens* was not the only hominin with linguistic abilities. Neanderthals, who evolved some 230,000 years ago, had the neural connections to the tongue, diaphragm and chest muscles necessary to articulate intricate sounds and control breathing for speech. Evidence comes from the size of holes in the skull and vertebrae through which the nerves serving these areas pass. What's more, Neanderthals shared the human variant of the *FOXP2* gene, crucial for forming the complex motor memories involved in speech. Assuming this variant arose just once, speech predates the divergence of the human and Neanderthal lines around 500,000 years ago.

Indeed, it appears that *Homo heidelbergensis* already had the gift of the gab 600,000 years ago when they first appeared in Europe. Fossilised remains show they had lost a balloon-like organ connected to the voice box that allows other primates to produce loud, booming noises to impress their opponents. "That's a big disadvantage – we can't have lost them for nothing," says Bart de Boer at the University of Amsterdam in the Netherlands. His models suggest that air sacs would blur differences between vowels, making it hard to form

For older ancestors, the fossil record does not speak so eloquently. However, Robin Dunbar at the University of Oxford notes that the most recent hominin to show evidence of ape-like neural connections in the diaphragm and chest is 1.6 million years old, suggesting speech evolved sometime between then and 600,000 years ago (*The Human Story*, Faber and Faber, 2004). To complicate matters further, language may have started with hand gestures, before eventually becoming vocal. If so, hominins could have been conversing in sign language long before adaptations for speech left their mark in the fossil record.

Even interpreting the available evidence is problematic because a hominin capable of speech cannot necessarily hold a meaningful conversation. Dunbar suggests that hominin voices might have evolved to sing by the campfire. Like birdsong, they would not have carried much specific information, but the activity would have been important for group bonding. But Stringer points out that *Homo heidelbergensis* and Neanderthals built complex tools and hunted dangerous animals – activities that would have been very difficult to coordinate without at least some primitive kind of language.

Indisputable evidence of speech conveying complex ideas comes only with the cultural sophistication and symbolism that is associated with *Homo sapiens*. But the first words, whenever they were spoken, started a chain of events that changed our relationships, society and technology, and even the way we think. David Robson

400,000

300,000

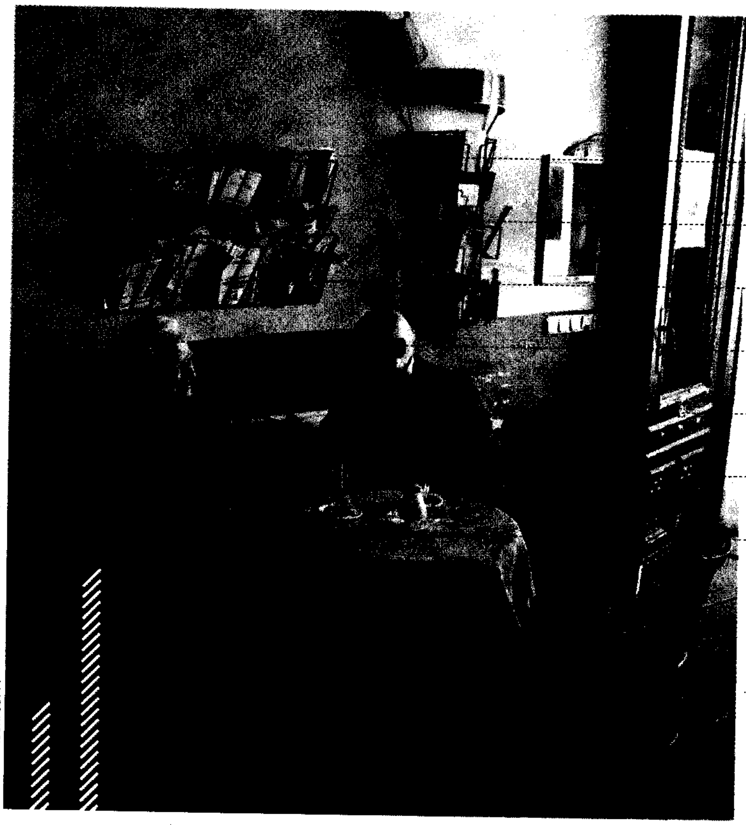
230,000 YA

Neanderthals evolve (brain volume 1300 cm³)

200,000

200,000 YA

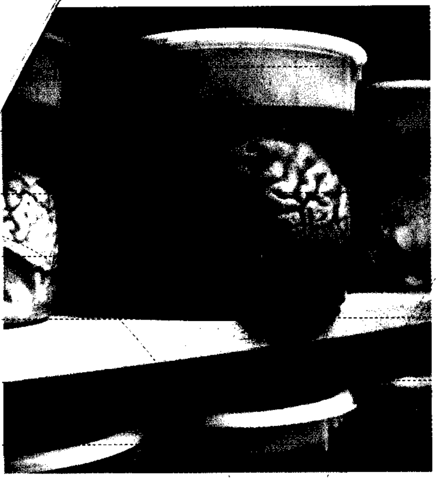
Homo sapiens evolves (brain volume 1300 cm³)



CHEV WILKINSON/GETTY

Hand gestures may have led naturally to language

vice as
should be
of our size



STEEVE IUNCKER/AGENCE VU/CAMERAPRESS

Why are our brains so big?

A SINGLE mutation may have cleared the way for rapid brain evolution. Other primates have strong jaw muscles that exert a force across the whole skull, constraining its growth. But around 2 million years ago a mutation weakened this grip in the human line. A brain growth spurt began soon after (*Nature*, vol 428, p 415).

What drove this spurt is another matter. The environment probably presented mental challenges. Social developments would have played a part, too. To test the relative importance of these pressures, David Geary at the University of Missouri in Columbia compared the skull size of various hominins against environmental conditions each lived in, such as the estimated variation in annual temperatures, and against proxies for social pressure, such as group size. Both were associated with bigger brains, but the difficulties of navigating a larger social network had the greatest impact (*Human Nature*, vol 20, p 67).

A big brain is incredibly hungry, so early humans needed to change their diet to support it. The transition to eating meat would have helped. So would the addition of seafood about 2 million years ago, providing omega-3 fatty acids for brain building (*Proceedings of the National Academy of Sciences*, vol 107, p 10002). Cooking might have helped too, by easing digestion. This would have allowed ancestral humans to evolve smaller guts and devote the spare resources to brain building.

Big brains come at a price, however, including the dangers of giving birth. By the time the benefits no longer outweighed the costs, we had a 1.3 kilogram lump of jelly smart enough to question its own existence. **David Robson**

100,000 90,000 80,000 70,000 60,000

125,000 YA

Humans leave Africa for Near East

70,000 YA

Last ice age begins

Evolution of body louse (origins of clothing?)

Why did we lose our fur?

MAMMALS expend huge amounts of energy just keeping warm. A pelt is nature's insulation. Why would we forgo that benefit? The most imaginative explanation is that our ancestors went through an aquatic phase millions of years ago and jettisoned their fur, which is a poor insulator in water, just as cetaceans have done. Critics say that if you want to keep warm in water you need to be round and lardy, not long and limby. Worse, the "aquatic ape" theory lacks fossil evidence to back it up.

More popular is the idea that we lost our fur when overheating, not cooling, became the biggest risk. "We don't pant or have large ears like elephants," says Chris Stringer of London's Natural History Museum. "Our only way to cool down is to sweat, and with thick fur that's inefficient." This wouldn't have been a problem in the shady forest, but when our ancestors moved to more open ground, natural selection would have favoured individuals with very fine hair to help cooling air circulate around their sweaty bodies (*Journal of Human Evolution*, vol 61, p 169). But sweating requires a large fluid intake, which means living near rivers or steams, whose banks tend to be wooded and shady – thus reducing the need to sweat. What's more, the Pleistocene ice age set in around 1.6 million years ago and even in Africa the nights would have been chilly.

PIPER MACKAY/GETTY

One advantage of exposed skin is that it advertises good health

Mark Pagel at the University of Reading, UK, points out that other animals on the savannah have hung on to their fur. He argues that we did not shed our pelts until we were smart enough to deal with the consequences, which was probably after modern humans evolved, about 200,000 years ago. "We can make things to compensate for fur loss such as clothing, shelter and fire." Then, Pagel contends, natural selection favoured less hairy individuals because fur harbours parasites that spread disease. Later, sexual selection lent a hand, as people with clear, unblemished skin advertising their good health became the most desirable sexual partners and passed on more genes (*Proceedings of the Royal Society B*, vol 270, p S117).

To confuse things still further, circumstantial evidence points to a very early denuding. The pubic louse evolved around 3.3 million years ago, says Mark Stoneking at the Max Plank Institute of Evolutionary Anthropology in Leipzig, Germany, and it could not have done so until ancestral humans lost their body fur, creating its niche (*BMC Biology*, DOI: 10.1186/1741-7007-5-7). What's more, he has dated the evolution of body lice, which live in clothing, to around 70,000 years ago (*Current Biology*, vol 13, p 1414). So it looks like our ancestors wandered around stark naked for a very long time. **Kate Douglas**

Why did we go global?

OUR ancestors have achieved some epic migrations. *Homo erectus* made the first great trek out of Africa and into east Asia 1.8 million years ago. Around a million years later, the predecessors of Neanderthals turned up in Europe. And 125,000 years ago, *Homo sapiens* made an early foray into the Middle East. None of these populations lasted. But some 65,000 years ago, one group of modern humans left Africa and conquered the world - an extraordinary achievement for any species, let alone a puny, furless ape. What possessed them to spread so far and wide?

It may have begun with a big squeeze. All humans belong to one of four mitochondrial lineages (L0, L1, L2 and L3) corresponding to four ancestral mothers, but only L3 is found outside Africa. Quentin Atkinson at the University of Auckland, New Zealand, and colleagues have found that this lineage experienced a population explosion in the 10,000 years leading up to the exodus (*Proceedings of the Royal Society B*, vol 276, p 367). So overcrowding in the Horn of Africa may have pushed the group to cross the Red Sea and move along the southern coast of Asia.

That still leaves the question of why numbers increased. Atkinson notes that for 100,000 years the African climate had oscillated between drought and floods before becoming stable around 70,000 years ago. Perhaps the environmental instability had forced early humans to become more inventive, with adaptations that helped population expansion once conditions improved.

Paul Mellars at the University of Cambridge has argued that the explosion in numbers was driven by a major increase in the complexity of technological, economic, social and cognitive behaviour (*Proceedings of the National Academy of Sciences*, vol 103, p 9381). The ability to control fire came much earlier, as, probably, did language. But the period does see a blossoming of innovation such as the manufacture of complex tools, efficient exploitation of food sources, artistic expression

4%

Maximum Neanderthal genes in modern humans

60,000 | 50,000 | 40,000 | 30,000

50,000 YA

"Great leap forward", a human cultural revolution

Neanderthals and humans interbreed?

45,000 YA

Colonisation of Australia

40,000 YA

Denisovans in Siberia

24,000 YA

Neanderthals become extinct

FRANK FRANKLIN/ASSOCIATED PRESS

Our DNA holds telltale signs of the mating antics of our ancestors

Are some of us hybrids?

COMPARING modern human DNA with ancient hominin sequences has revealed that between 1 and 4 per cent of the genome of everyone of non-African descent is inherited from Neanderthals (*Science*, vol 328, p 710). Melanesians also have 7 per cent derived from Denisovans (*Nature*, vol 468, p 1053). "This is an unequivocal signal that humans mated with these other populations," says Richard Green at the University of California, Santa Cruz.

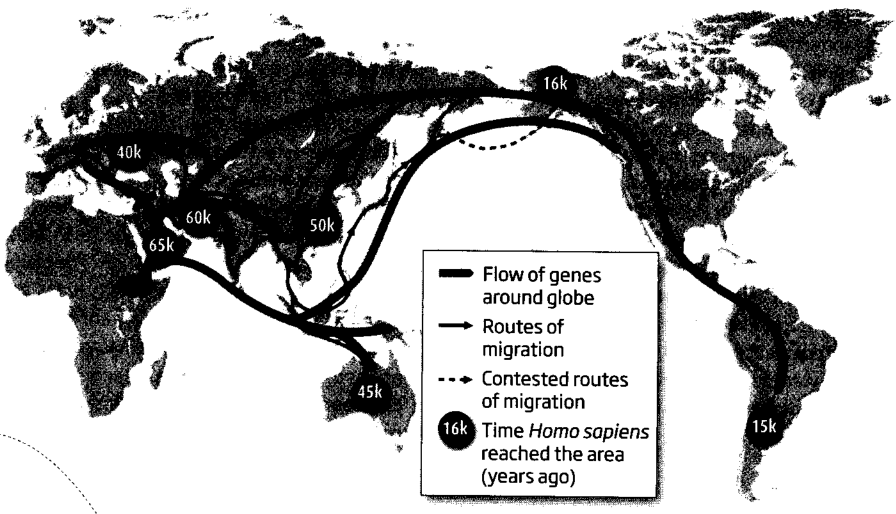
These studies suggest that mating between modern humans and our cousins was relatively infrequent, and possibly confined to a single time and place for each species. In the case of Neanderthals it probably happened more than 50,000 years ago in the Middle East.

and symbolic ornamentation. These cultural advances would have been crucial, says Mark Pagel at the University of Reading, UK. "Not only can we walk, we can change the world when we get there." This flexibility would have propelled migrants ever onward, he notes, as populations quickly reached carrying capacity and individuals moved into new territory to avoid competition.

"Some of it would have been accidental," adds Chris Stringer of London's Natural History Museum: the peopling of Australia may have come about when seafarers travelling between islands were blown further afield. Genetic mutations could also have made us more adventurous. For example, the so-called novelty-seeking gene, *DRD4-7R*, is more common in populations that migrated fastest and furthest from Africa (*American Journal of Physical Anthropology*, vol 145, p 382). "Of course there is the human spirit – to climb the unclimbed mountain," says Stringer. Kate Douglas

To boldly go

After *Homo sapiens* left Africa 65,000 years ago they spread out across the globe



20,000

10,000

18,000 YA

Indonesian *Homo floresiensis* ("hobbit") becomes extinct

15,000 YA

Colonisation of the Americas

Not everyone is convinced, however. "As humans spread across Europe within the past 45,000 years, they would have met Neanderthals on every street corner," says Mellars. "Yet there's no evidence that interbreeding took place here." Why? Green counters that this could just be a numbers game: if there were many more humans than Neanderthals, the DNA signal of mating in Europe would have been weak or lost entirely from the modern human genome.

But there is an alternative explanation for the presence of Neanderthal DNA in the human genome. Imagine that ancient hominin populations in Africa, each with a slightly different genetic makeup, were separated from one another. If one group gave rise to all the hominins that lived outside Africa, while other populations became the ancestors of all Africans, then even without subsequent interbreeding the non-African and Neanderthal populations would share some DNA that African populations would lack. This possibility was mentioned by Green and colleagues in their original paper and has been explored further by Andrea Manica at the University of Cambridge, who believes that it could explain the distribution pattern of Neanderthal genes found today.

But even if we accept that some interbreeding occurred – and most people do – does that make us hybrids? Martin Richards at Huddersfield University in the UK notes that the species concept is "very fuzzy", making it difficult to draw neat lines between groups. One definition of species is a group that cannot mate and produce viable offspring with other species, so the genetic analysis calls into question whether Neanderthals and Denisovans were different species to humans at all. Indeed, Neanderthals are sometimes considered a subspecies of *Homo sapiens*.

7%

Denisovan genes in Melanesians

The species issue is a distraction, according to Green. "We can define our genetic relationships with Neanderthals and Denisovans in exquisite detail without putting the label of species on these groups." At a more visceral level, though, the question of whether or not our ancestors mated with other species is central to the way we think about ourselves. **Dan Jones**

Did we exterminate the Neanderthals?

MORE than 100,000 years ago, a group of Neanderthals set up home in some huge caverns in the Rock of Gibraltar. At the time, the species was spread far and wide across Europe and Asia, but as the millennia passed, populations dwindled, leaving the Gibraltans among the last, isolated survivors. By 24,000 years ago they, too, had succumbed.

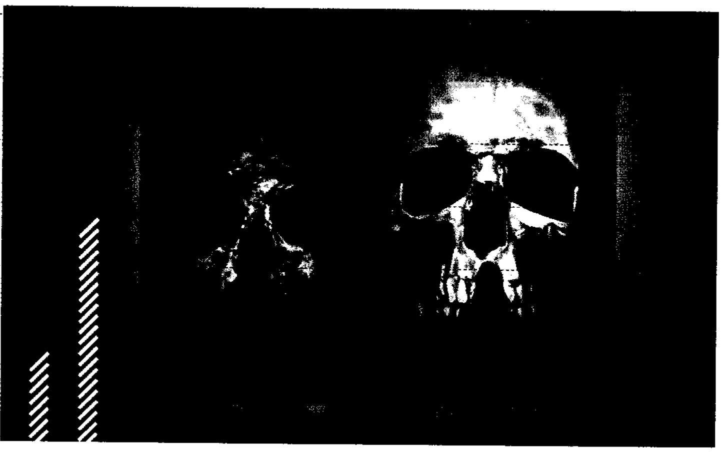
Most theories of Neanderthal extinction point the finger of blame squarely at us. As our ancestors swept across Asia and Europe, they may have brought diseases that the Neanderthals could not fight. Alternatively, we may have outsmarted them in the competition for food and land. Although their brains were as big as ours, recent research suggests they devoted more brain volume to vision, allowing them to see better in the dark north, but leaving less grey matter available for other skills, such as cooperation and advanced tool use (*Biology Letters*, vol 8, p 90). Even if we made love, not war, we aided the Neanderthal's downfall.

Yet the case against us is not watertight. Neanderthal sites show little sign of direct contact with modern humans, let alone competition or warfare, says Clive Finlayson of the University of Toronto, Canada. Instead he blames the Neanderthal's fall, and our rise, on climate change (*The Humans Who Went Extinct*, Oxford University Press, 2009). With the onset of the last glacial period, around 100,000 years ago, the climate became erratic, and across much of northern Europe vegetation died back leaving cold, windswept plains. *Homo sapiens* had projectile weapons that allowed them to hunt at a distance, but Neanderthals were adapted to hunting at close range, using bushes to sneak up on prey until they were close enough to thrust a spear into its side. With their cover gone, "they were the living dead", says Finlayson. The last Neanderthals lingered in more climatically stable regions before other pressures such as drought or disease sounded the death knell for their weakened populations.

Chris Stringer of London's Natural History Museum doesn't let us off the hook so easily. He agrees that climate is one piece of the puzzle, but thinks we should not downplay competition with modern humans. "It was a double whammy," he says. Who knows, if the fickle climate had tipped the odds the other way, perhaps a Neanderthal would be sitting in your place. David Robson

9000 8000 7000 6000 5000 4000

If "hobbits" exist, what else might be out there?



JEAN PAUL GUILLOTEAU/EXPRESS-REA

Are there any other hominins left?

LEGENDS of human-like creatures, such as Bigfoot, the Yeti and the Yowie have entranced people for centuries. They make for good stories, but could there be any truth in them?

It seems unlikely. Recently, Jeff Lozier at the University of Alabama in Tuscaloosa examined the location of all Bigfoot, or Sasquatch, sightings. He found that these "haunts" are identical to those of the black bear, suggesting it could simply be a case of mistaken identity (*Journal of Biogeography*, vol 36, p 1623). "I've never seen anything that has convinced me," adds David Coltman at the University of Alberta in Edmonton, Canada, who recently analysed a tuft of hair from a supposed Bigfoot to find that it came from a bison. Coltman concedes that new species of primate are occasionally found in remote regions, so there is a slim chance that there may be something out there. "But it's very unlikely that they could fly under the radar for so long."

Nevertheless, a few scientists are willing to contemplate the idea that *Homo sapiens* is not alone. Jeffrey Meldrum at Idaho State University in Pocatello, points out that other hominin species coexisted alongside our ancestors for most of human history. That's not all. Our family tree can still surprise us, as happened with the discovery of *Homo floresiensis*, aka the "hobbit", nine years ago (the left-hand skull in the picture). This pint-sized hominin lived on the Indonesian island of Flores until 18,000 years ago. Just two years ago came another surprise when genetic analysis revealed a previously unknown species, the Denisovans, living in Siberia around 40,000 years ago (*New Scientist*, 30 July 2011, p 34).

Meldrum finds it easy to imagine that small groups of our cousins could be clinging on in remote areas such as the Himalayas and the Caucasus. They could even be a bit closer to home. In 1996, he heard reports of 38-centimetre-long, ape-like tracks in the Blue mountain forests of Oregon. He arrived expecting to see a poor hoax, but the prints showed an extraordinary level of anatomical detail. The toes were flexed at certain locations but more relaxed at others, for instance, as if the animal had been running for some stretches of its journey. Such details would be very difficult to fabricate, Meldrum says. "I'm not trying to convince people of the existence of the Sasquatch, but we shouldn't turn our back on the possibility." **David Robson** ■