At last, the story of how the naked ape conquered the world is being told. **Dan Jones** follows the trail

Going global

LONG before the Nike logo and McDonald's golden arches straddled the planet, there was a truly global brand. Before the worldwide web, before mass production and even before the first economist, our own species, *Homo sapiens*, had penetrated every corner of the globe, succeeding in an unrivalled array of environments, from the unforgiving cold of the Arctic tundra to the blazing heat of the Australian outback and the humid forests of the Amazon. How did we achieve this global dominance? What routes did our ancestors take as they moved into lands unknown and traversed uncharted seas? When did they move and spread? How this particular naked ape became such an evolutionary success story is a question that has long intrigued us.

Now, palaeontologists, archaeologists and geneticists are finally piecing it together. As a coherent picture emerges, however, new mysteries arise. It is looking likely that our species appeared far earlier than previously suspected – and remained in Africa for tens of thousands of years before going global: "All dressed up and going nowhere," as archaeologist Clive Gamble at the Royal Holloway University of London, puts it. Why the delay? Yet when our ancestors finally flocked onto the world stage, their spread was remarkably rapid. What caused them to explode out of Africa when they did? What circumstances suddenly allowed those early humans to smash down their boundaries like no species before or since?

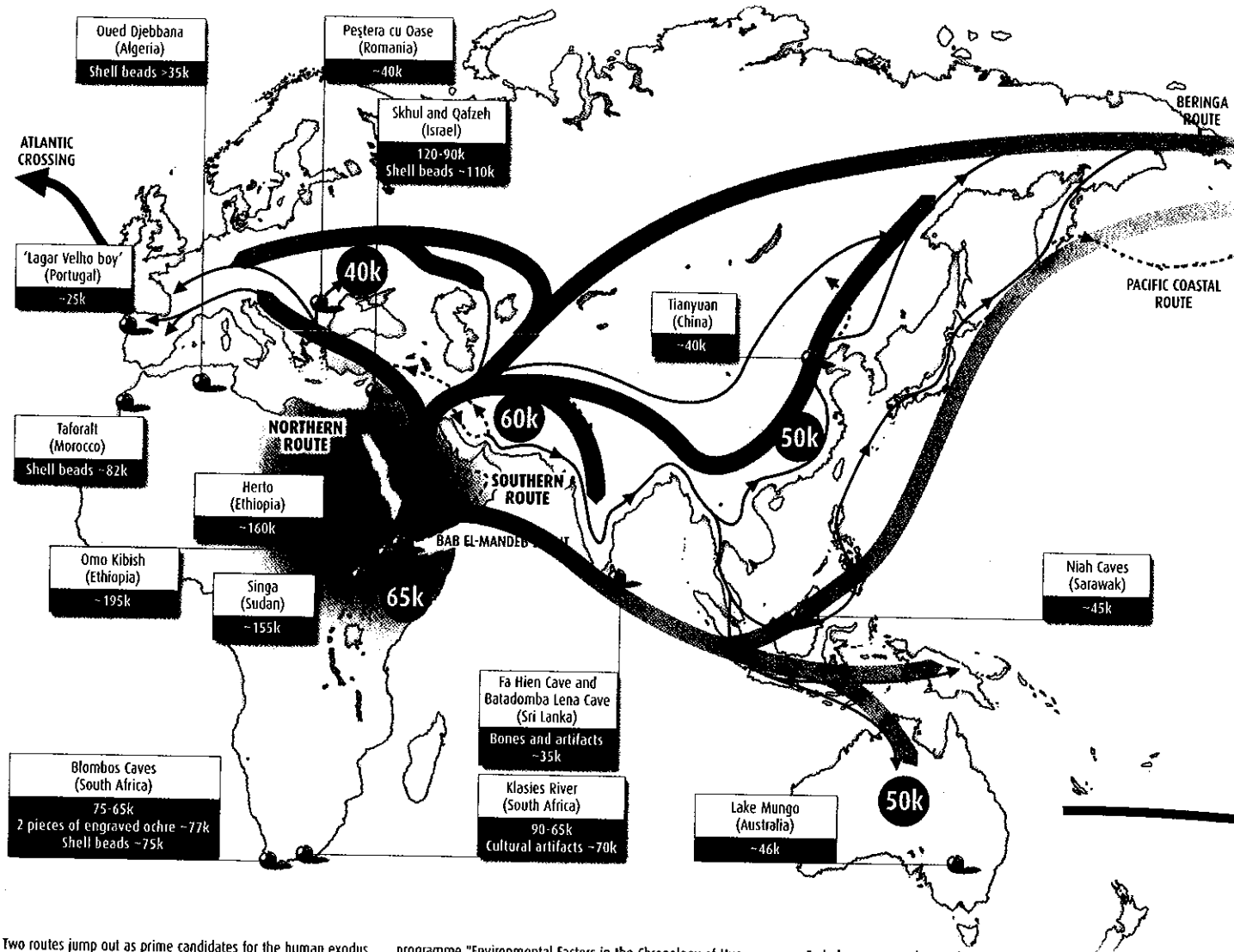
Until quite recently, *H. sapiens* was thought to have evolved just 100,000 years ago. Over the past two decades, however, a consensus has grown that anatomically modern humans emerged in Africa at least 160,000, and possibly 200,000, years ago. This shift in thinking began in 1987 with landmark research led by Allan Wilson of the University of California, Berkeley. Using genetic analysis to construct an evolutionary tree of mitochondrial DNA – genetic material we inherit solely from our mothers – Wilson found that we can all trace our ancestry back to a single woman who lived in east Africa some 200,000 to 150,000 years ago – the "mitochondrial Eve".

The case for such early origins has since been boosted by accumulating fossil evidence. In 2003, a team lead by palaeontologist Tim White of the University of California, Berkeley, dated fossil remains of a subspecies of *H. sapiens* from Herto in Ethiopia at about 160,000 years old (*Nature*, vol 423, p 747). Two years later, Ian McDougall at the Australian National University, Canberra, and colleagues pushed our origins even further back, dating fossil remains found in 1967 at Omo Kibish, Ethiopia, to as long as 195,000 years ago (*Nature*, vol 433, p 733). Although the Omo Kibish date is contested, few doubt that our species is much older than we once thought.

At the same time, it is becoming clear that the diaspora of *H. sapiens* out of Africa happened more recently, and more rapidly, than has traditionally been accepted. Skeletal remains from Skhul and Qafzeh in Israel dating from 120,000 to 90,000 years ago are the oldest known traces of modern humans outside Africa. Discovered in the 1930s, these were once thought to represent the leading edge of a successful wave of colonisation that would take our newly evolved species north and west into Europe and, eventually, eastward across the globe. However, all evidence of human habitation beyond Africa disappears around 90,000 years ago, only ▶

THE MIGRATION OF ANATOMICALLY MODERN HUMANS

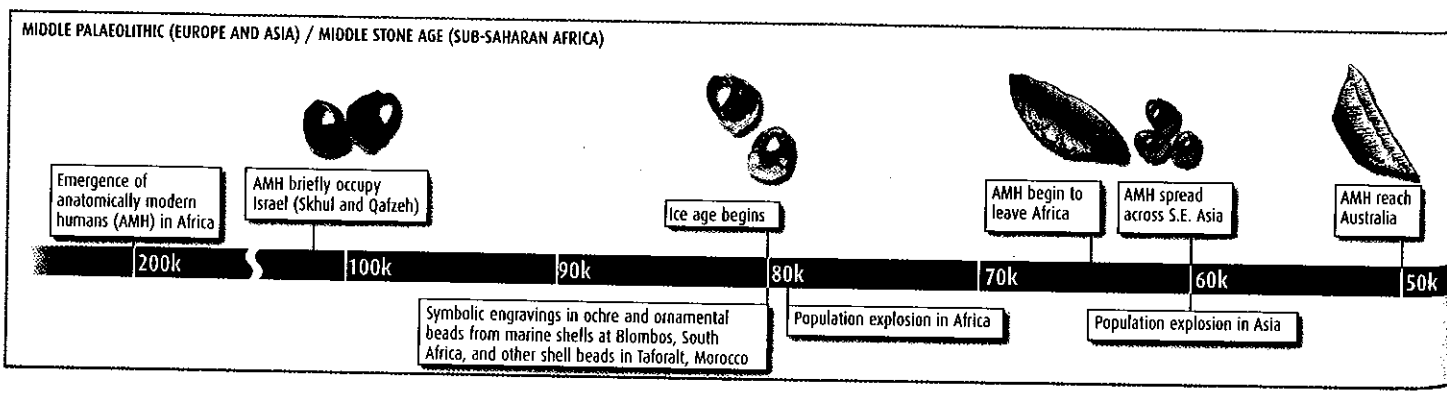
Evidence from fossils, ancient artefacts and genetic analyses combine to tell a compelling story



Two routes jump out as prime candidates for the human exodus out of Africa. A northern route would have taken our ancestors from their base in eastern sub-Saharan Africa across the Sahara desert, then through Sinai and into the Levant. An alternative southern route may have charted a path from Djibouti or Eritrea in the Horn of Africa across the Bab el-Mandeb strait and into Yemen and around the Arabian peninsula. The plausibility of these two routes as gateways out of Africa has been studied as part of the UK's Natural Environment Research Council's programme "Environmental Factors in the Chronology of Human Evolution & Dispersal" (EFCHED).

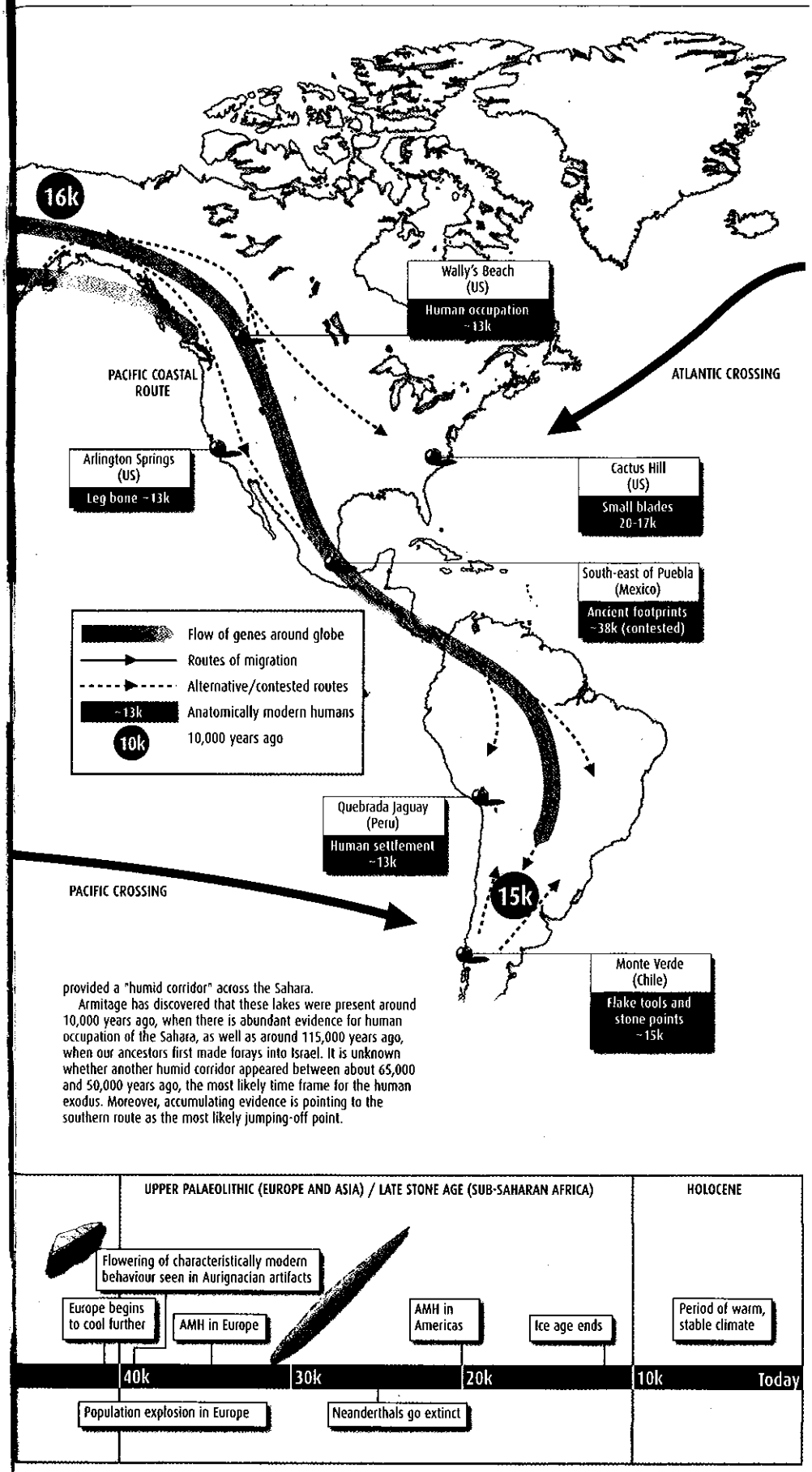
During the last ice age, from about 80,000 to 11,000 years ago, sea levels dropped as the ice sheets grew, exposing large swathes of land now submerged under water and connecting regions now separated by the sea. By reconstructing ancient shorelines, the EFCHED team found that the Bab el-Mandeb strait, now around 30 kilometres wide and one of the world's busiest shipping lanes, was then a narrow, shallow channel.

Early humans may have taken this southern route out of Africa. The northern route appears easier, especially given the team's finding that the Suez basin was dry during the last ice age. But crossing the Sahara desert is no small matter. EFCHED scientist Simon Armitage of the Royal Holloway University of London has found some clues as to how this might have been possible. During the past 150,000 years, North Africa has experienced abrupt switches between dry, arid conditions and a humid climate. During the longer wetter periods huge lakes existed in both Chad and Libya, which would have



provided a "humid corridor" across the Sahara.

Armitage has discovered that these lakes were present around 10,000 years ago, when there is abundant evidence for human occupation of the Sahara, as well as around 115,000 years ago, when our ancestors first made forays into Israel. It is unknown whether another humid corridor appeared between about 65,000 and 50,000 years ago, the most likely time frame for the human exodus. Moreover, accumulating evidence is pointing to the southern route as the most likely jumping-off point.



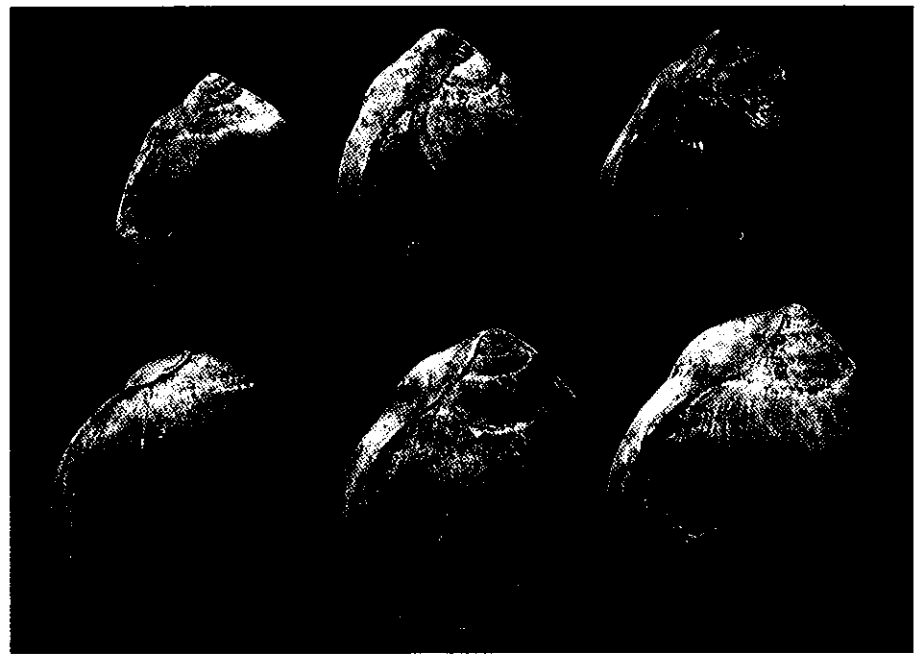
to emerge again much later. The finds in Israel are widely believed to represent a precocious but short-lived surge of humanity into the wider world. Small groups may have made tentative forays out of the African homeland, but it would be tens of thousands of years before we were to ready to conquer the planet.

The route that our ancestors took out of Africa is also being re-evaluated. Based on the evidence of the early occupation of the Middle East, the idea took hold that when early modern humans eventually began their global migration, they took a "northern route" through the Levant and up into Europe. Now that is being challenged. The latest discoveries point to early and widespread occupation of south-east Asia and Australasia, with migration to the north and then west into Europe happening later.

Asia first

This year, for example, skeletal remains found in Niah Cave in Sarawak, on the island of Borneo, were dated to between 45,000 and 40,000 years old (*Journal of Human Evolution*, vol 52, p 243). Many researchers now believe Australia was also colonised around this time, following a recent re-dating of skeletal remains discovered near Lake Mungo in New South Wales, which puts them at 46,000 years old. Added to these are the newly described fossils from Tianyuan Cave, near Beijing, China, which at 40,000 years of age are the oldest modern human remains from eastern Eurasia (*Proceedings of the National Academy of Sciences*, vol 104, p 6573). While some of our ancestors explored the far east of Asia, other groups were beginning to enter Europe. Skeletal remains from Peştera cu Oase in Romania also date at about 40,000 years old. The oldest fossils in western Europe are slightly younger, between 37,000 and 36,000 years old. Only the Americas seem to have been colonised much later, towards the end of the last ice age, and probably no more than 16,000 years ago (*New Scientist*, 13 August).

A similar story about human migration is also being dug from the genomes of living people. As groups of humans migrated to new areas, they carried with them rare genetic mutations from their ancestral population. These "signature" mutations were then passed to the future generations that inhabited newly colonised regions, making the previously rare mutations more common in different places. Genetic mutation is an ongoing process, so further unique variations would also have sprung up as bands of humans moved from place to place, populating new lands. From the modern geographical distribution of genetic variants we can work backwards to chart possible routes of migration. Furthermore, ▶



using estimates of how frequently such mutations arise, we can work out the likely date at which specific variants appeared.

Take the genetic marker M130. Globally speaking, it is a relatively rare sequence of base pairs on the Y chromosome. It increases in frequency from 10 per cent in Malaysia to 15 per cent in New Guinea to 60 per cent in Australia, charting the eastward spread of small groups carrying the M130 mutation. Other genetic studies put approximate dates to migration patterns such as these. For example, analysis of the variation in mitochondrial DNA among Andaman islanders and people now living in the Malaysian peninsula suggest that modern humans colonised this region at least 55,000 years ago, and possibly as long as 65,000 years ago (*Science*, vol 308, p 1034). This fits broadly with genetic evidence published earlier this year revealing that aboriginal Australians are most closely related to New Guineans, and indicating that both landmasses were probably settled by the same colonisation event around 50,000 years ago (*Proceedings of the National Academy of Sciences*, vol 104, p 8726).

There is also genetic evidence for the later spread into Europe. Spencer Wells at the National Geographic Society in Washington DC, has charted the geographic distribution of genetic markers on the Y chromosome of men now living in Eurasia. He found that about 40,000 years ago populations started to diverge in the Middle East, some moving south into India, and others moving north through the Caucasus and then splitting into a westward arm that led across northern Europe and an eastward arm reaching across Russia and into Siberia (see Map).

These later migrations would have taken people into the heart of Eurasia, but it seems likely that the first migrants skirted the coast. Where once our exodus from Africa was thought to have begun with a trek across the Sahara desert and then north through Sinai to the Levant, evidence increasingly suggests that our ancestors first left the continent from the Horn of Africa, across a then narrower Bab el-Mandeb strait, swung around the Arabian peninsula, past Iraq, and then followed the coast of Iran to the east – a single dispersal along the "southern route" (see Map).

As well as fitting with the genetic and fossil evidence, this coastal route makes perfect ecological sense. Early modern humans were clearly able to exploit the resources of the sea, as attested to by dumps of clam and oyster shells found in Eritrea in eastern Africa, dating from around 125,000 years ago, and similar marine remains in southern Africa from between 115,000 and 100,000 years ago. Sticking with what they knew, beachcombing *H. sapiens* would have been able to move rapidly along the coastline without having to invent new ways of making a living or adapting to unfamiliar ecological conditions.

"This 'cultural great leap forward' equipped them to conquer the world"

Archaeological traces of migration along the southern coastal route are patchy but consistent with this picture. The earliest evidence of settlement by modern humans in south Asia comprises stone tools and human remains discovered in the Fa Hien and Batadomba Lena caves in Sri Lanka, dating from up to 35,000 years ago. What's more, it looks as if these people were equipped with the same sort of cultural repertoire as existed in Africa between 60,000 and 50,000 years ago. "The similarities between Africa and India are not coincidental, and fit in beautifully with the DNA evidence," says Paul Mellars, an archaeologist at the University of Oxford. Although none of these artefacts is more than 35,000 years old, that may simply reflect the fact that sea levels are about 100 metres higher today than they were 50,000 years ago. Any artefacts or bones left by the first coastal migrants are now buried beneath the sea.

Yet the crucial questions remain: why did humans leave Africa when they did, and what enabled them to achieve world domination this time, where previous migrations had petered out? Richard Klein, an anthropologist at Stanford University in California, has championed the idea that fully modern behaviour appeared in a relatively sudden burst in Africa around 50,000 years ago. Such behaviours encompass the manufacture and use of complex bone and stone tools, efficient and intensive exploitation of local food resources and, perhaps most significantly, symbolic ornamentation and artistic expression. These changes were the result of a few significant genetic changes affecting cognition and intellectual capacity, Klein suggests. In particular, he speculates that *FOXP2*, the gene associated with language, may have mutated around this time, allowing for improved cultural transmission of ideas. Klein believes that whatever the contributing

Ancient shell beads point to a cultural flowering some 80,000 year ago

factors, this "cultural great leap forward" tipped humans over into modernity and equipped them with the creativity, skills and tools needed to conquer the rest of the world.

By contrast, other researchers believe that the behavioural modernity that underpins the human success story evolved much earlier. They point to a growing array of artefacts such as pieces of engraved ochre found in Blombos Cave in South Africa, which date to around 77,000 years ago, and various discoveries of ancient "beads", including pierced shells found in Morocco and dated to 82,000 years ago (*Proceedings of the National Academy of Sciences*, vol 104, p 9964).

It is possible, however, that such finds might simply reflect a gradual accumulation of more modern behavioural patterns, rather than the appearance of fully modern minds. "If you look broadly at the archaeological record between 100,000 and 40,000 years ago," says anthropologist Erik Trinkaus of Washington University in St Louis, Missouri, "you find occasional artefacts, such as symbolic ornamentation, that seem to be indicative of modern behaviour, but they are extremely rare."

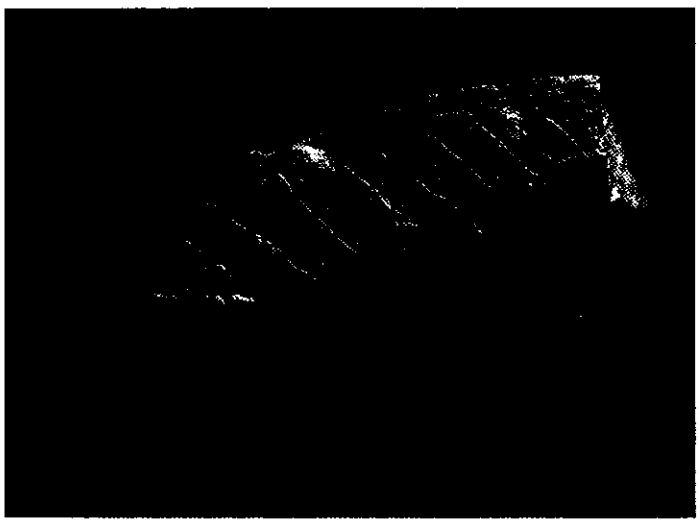
Last year Mellars proposed a new model to explain the out-of-Africa diaspora that aims to tie together these controversial archaeological remains with recent genetic findings (*Proceedings of the National Academy of Sciences*, vol 103, p 9381). Key to his idea are genetic studies that point to a series of population explosions, first in Africa and later in Asia and then Europe. Rapid population growth leaves a telltale signature in the number of differences in mitochondrial DNA between pairs of individuals within a specific population: as the time since the population explosion increases, so do the DNA mismatches. This analysis shows African populations were rocketing 80,000 to 60,000 years ago, neatly matching the evidence for an early flowering of behavioural modernity. "There is an extraordinary coincidence between these dates and the appearance of the first bone tools, first artistic designs such as the Blombos ochre, new forms of stone tools, and perforated shells and ornamentation," says Mellars.

Population explosion

According to his model, human behaviour was altering between 80,000 and 70,000 years ago in ways that led to major technological and social changes in south and east Africa. Key innovations, including improved weaponry for hunting, new use of starchy wild plants to eat, the expansion of trading networks, and possibly the discovery of how to catch fish, enabled modern humans to make a better living off the land and sea. Mellars says all this led to a massive and rapid population expansion, perhaps in just a small source region in Africa, between 70,000 and 60,000 years ago. This growing population, equipped with more complex technology, was finally able to push out of Africa and into southern Asia from around 65,000 years ago. What's more, the discovery of similar growth in Asian populations around 60,000 years ago ties in with evidence that humans were trekking along the southern coast of Asia at least 55,000 years ago. It is a neat story but, not surprisingly, Klein and other supporters of the human "great leap forward" dispute it.

Whether behavioural modernity and the capacity for complex culture arose gradually or in a sudden burst, questions still remain about what encouraged the great leaps in technological know-how and cultural sophistication of early modern humans. While genetic changes are likely to have been important, as Klein argues, climate may also have played a decisive role. A study of cores taken from Lake Malawi and published online in September (*Proceedings of the National Academy of Sciences*, DOI: 10.1073/pnas.0703874104) reveals that between around 150,000 and 70,000 years ago the African climate was highly variable, oscillating between periods of drought and flood, before becoming more stable and damp. "Our research suggests that the population expansion and subsequent spreading of out-of-Africa colonisers may have been aided by the newly stabilised climate," says Christopher Scholz, from Syracuse University, New York, who led the international team. The preceding era of wild climate fluctuation would have increased the pressure on our ancestors to adapt or die, plausibly driving changes in social arrangements, technology and allowing the most adaptable and successful humans to survive and proliferate. So climatic upheaval may have primed our forebears for world domination, while stability then allowed them to multiply and conquer the Earth.

The human story has always been hotly contested. Now, at last, the basic plot is finally taking shape. While the fragmentary and ambiguous nature of the evidence means that the fine details of our species' biography are still obscure, there is every reason to expect that the synthesis of genetic and palaeontological findings will in time reveal the whole story. Then, we will be able to answer two of life's most fundamental questions: were did we come from and how did we get here? ●



A picture of modernity. Carved ochre found in a cave in South Africa

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