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The proper study of mankind

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New theories and techniques have revolutionised our understanding of humanity's past and present, says Geoffrey Carr (interviewed here)

SEVEN hundred and forty centuries ago, give or take a few, the skies darkened and the Earth caught a cold. Toba, a volcano in Sumatra, had exploded with the sort of eruptive force that convulses the planet only once every few million years. The skies stayed dark for six years, so much dust did the eruption throw into the atmosphere. It was a dismal time to be alive and, if Stanley Ambrose of the University of Illinois is right, the chances were you would be dead soon. In particular, the population of one species, known to modern science as *Homo sapiens*, plummeted to perhaps 2,000 individuals.

The proverbial Martian, looking at that darkened Earth, would probably have given long odds against these peculiar apes making much impact on the future. True, they had mastered the art of tool-making, but so had several of their contemporaries. True, too, their curious grunts allowed them to collaborate in surprisingly sophisticated ways. But those advantages came at a huge price, for their brains were voracious consumers of energy—a mere 2% of the body's tissue absorbing 20% of its food intake. An interesting evolutionary experiment, then, but surely a blind alley.

This survey will attempt to explain why that mythical Martian would have been wrong. It will ask how these apes not only survived but prospered, until the time came when one of them could weave together strands of evidence from fields as disparate as geology and genetics, and conclude that his ancestors had gone through a genetic bottleneck caused by a geological catastrophe.

Not all of his contemporaries agree with Dr Ambrose about Toba's effect on humanity. The eruption certainly happened, but there is less consensus about his suggestion that it helped form the basis for what are now known as humanity's racial divisions, by breaking *Homo sapiens* into small groups whose random physical quirks were preserved in different places. The idea is not, however, absurd. It is based on a piece of evolutionary theory called the

founder effect, which shows how the isolation of small populations from larger ones can accelerate evolutionary change, because a small population's average characteristics are likely to differ from those of the larger group from which it is drawn. Like much evolutionary theory, this is just applied common sense. But only recently has such common sense been applied systematically to areas of anthropology that have traditionally ignored it and sometimes resisted it. The result, when combined with new techniques of genetic analysis, has been a revolution in the understanding of humanity's past.

And anthropology is not the only human science to have been infused with evolutionary theory. Psychology, too, is undergoing a makeover and the result is a second revolution, this time in the understanding of humanity's present. Such understanding has been of two types, which often get confused. One is the realisation that many human activities, not all of them savoury, happen for exactly the same reasons as in other species. For example, altruistic behaviour towards relatives, infidelity, rape and murder are all widespread in the animal kingdom. All have their own evolutionary logic. No one argues that they are anything other than evolutionarily driven in species other than man. Yet it would be extraordinary if they were not so driven in man, because it would mean that natural selection had somehow contrived to wipe out their genetic underpinnings, only for them to re-emerge as culturally determined phenomena.

Understanding this shared evolutionary history with other species is important; much foolishness has flowed from its denial. But what is far more intriguing is the progress made in understanding what makes humanity different from other species: friendship with non-relatives; the ability to conceive of what others are thinking, and act accordingly; the creation of an almost unimaginably diverse range of artefacts, some useful, some merely decorative; and perhaps most importantly, the use of language, which allows collaboration on a scale denied to other creatures.

There are, of course, gaps in both sets of explanations. And this field of research being a self-examination, there are also many controversies, not all driven by strictly scientific motives. But the outlines of a science of human evolution that can explain humanity's success, and also its continuing failings, are now in place. It is just a question of filling in the canvas—or the cave wall.

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The long march of everyman

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It all started in Africa

OUT of Africa, always something new", wrote Caius Plinius Secundus, a Roman polymath who helped to invent the field of natural history. Pliny wrote more truly than he could possibly have realised. For one fine day, somewhere between 85,000 and 60,000 years before he penned those words, something did put its foot over the line that modern geographers draw to separate Africa from Asia. And that something—or, rather, somebody—did indeed start something new, namely the peopling of the world.

Writing the story of the spread of humanity is one of the triumphs of modern science, not least because the ink used to do it was so unexpected. Like students of other past life forms, researchers into humanity's prehistoric past started by looking in the rocks. The first fossilised human to be recognised as such was unearthed in 1856 in the Neander Valley near Dusseldorf in Germany. Neanderthal man, as this skeleton and its kin became known, is now seen as a cousin of modern humans rather than an ancestor, and subsequent digging has revealed a branching tree of humanity whose root can be traced back more than 4m years (see article).

Searching for human fossils, though, is a frustrating exercise. For most of their existence, people were marginal creatures. Bones from periods prior to the invention of agriculture are therefore excedingly rare. The resulting data vacuum was filled by speculation scarcely worthy of the name of theory, which seemed to change with every new discovery. Then, in the 1980s, a geneticist called Allan Wilson decided to redefine the meaning of the word "fossil". He did so in a way that instantly revealed another 6 billion specimens, for Wilson's method made a fossil out of every human alive.

Living fossils

In retrospect, Wilson's insight, like many of the best, is blindingly obvious. He knew, as any biologist would, that an organism's DNA carries a record of its evolutionary past. In principle, looking at similarities and differences in the DNA sequences of living organisms should allow a researcher to reconstruct the family tree linking those organisms. In practice, the sexual mixing that happens with each generation makes this tedious even with today's DNA-analysis techniques. With those available in the 1980s it would have been impossible. Wilson, however, realised he could cut through the problem by concentrating on an unusual type of DNA called mitochondrial DNA.

Mitochondria are the parts of a cell that convert energy stored in sugar into a form that the

rest of the cell can use. Most of a cell's genes are in its nucleus, but mitochondria, which are the descendants of bacteria that linked up with one of humanity's unicellular ancestors some 2 billion years ago, retain a few genes of their own. Mitochondrial genomes are easy to study for three reasons. First, they are small, which makes them simple to analyse. Second, mitochondria reproduce asexually, so any changes between the generations are caused by mutation rather than sexual mixing. Third, in humans at least, mitochondria are inherited only from the mother.

In 1987, Rebecca Cann, one of Wilson's students, applied his insight to a series of specimens taken from people whose ancestors came from different parts of the world. By analysing the mutational differences that had accumulated since their mitochondria shared a common ancestor, she was able to construct a matriline (or, perhaps more accurately, a matritree) connecting them.

The result was a revelation. Whichever way you drew the tree (statistics not being an exact science, there was more than one solution), its root was in Africa. *Homo sapiens* was thus unveiled as an African species. But Dr Cann went further. Using estimates of how often mutations appear in mitochondrial DNA (the so-called molecular clock), she and Wilson did some matridendrochronology. The result suggests that all the lines converge on the ovaries of a single woman who lived some 150,000 years ago.

There was much excited reporting at the time about the discovery and dating of this African "Eve". She was not, to be clear, the first female *Homo sapiens*. Fossil evidence suggests the species is at least 200,000 years old, and may be older than that. And you can now do a similar trick for the patriline using part of the male (Y) chromosome in the cell nucleus, because this passes only from father to son. Unfortunately for romantics, the most recent common ancestor of the Y-chromosome is a lot more recent than its mitochondrial equivalent. African Adam was born 60,000-90,000 years ago, and so could not have met African Eve. Nevertheless, these two pieces of DNA as they have weaved their ways down the generations have filled in, in surprising detail, the highways and byways of human migration across the face of the planet.

Sons of Adam, daughters of Eve

Detail, however is not the same as consensus, and there are two schools of thought about how people left Africa in the first place. Appropriately, some of their main protagonists are at the rival English universities of Oxford and Cambridge. The Oxford school, championed by Stephen Oppenheimer, believes that the descendants of a single emigration some 85,000 years ago, across the strait of Bab el Mandeb at the southern end of the Red Sea, are responsible for populating the rest of the world. The Cambridge school, championed by Robert Foley and Marta Mirazón Lahr, agrees that there was, indeed, a migration across this strait, though probably nearer to 60,000 years ago. However, it argues that many non-Africans are the descendants of at least one subsequent exodus.

Both schools agree that the Bab el Mandebites spread rapidly along the coast of southern Arabia and thence along the south coast of Asia to Australia, though Dr Oppenheimer has them turning inland, too, once they crossed the strait of Hormuz. But it is in describing what happened next that the two versions really part company, for it is here that the descendants of the Oxford migration run into the eruption of Toba.

That Toba devastated South and South-East Asia is not in doubt. Thick layers of ash from the eruption have been found as far afield as northern Pakistan. The question is whether there were people in Asia at the time. One of the most important pieces of evidence for Dr Oppenheimer's version of events is some stone tools in the ash layer in Malaysia, which he thinks were made by *Homo sapiens*. Molecular clocks have a regrettable margin of error, but radioactive dating is a lot more accurate. If he is right, modern humans must have left Africa before the eruption. The tools might, however, have been crafted by an earlier species of human that lived there before *Homo sapiens*.

For Dr Oppenheimer, the eruption was a crucial event, dividing the nascent human population of Asia into two disconnected parts, which then recolonised the intermediate ground. In the Cambridge version, *Homo sapiens* was still confined to Africa 74,000 years ago, and would merely have suffered the equivalent of a nuclear winter, not an ash-fall of up to five metres—though Dr Ambrose and his colleagues think even that would have done the population no good.

The Cambridge version is far more gentle. The descendants of its subsequent exodus expanded north-eastwards into central Asia, and thence scattered north, south, east and west—though in a spirit of open-mindedness, Sacha Jones, a research student in Dr Foley's department, is looking in the ash layer in India to see what she can find there.

Which version is correct should eventually be determined by the Genographic Project, a huge DNA-sampling study organised by Spencer Wells, a geneticist, at the behest of America's National Geographic Society and IBM. But both already have a lot in common. Both, for example, agree that the Americas seem to have been colonised by at least two groups. The Cambridge school, though, argues that one of these is derived ultimately from the first Bab el Mandeb crossing while the other is descended from the later migrants.

Both also agree that Europe received two waves of migration. The ancestors of the bulk of modern Europeans came via central Asia about 35,000 years ago, though some people in the Balkans and other parts of southern Europe trace their lines back to an earlier migration from the Middle East. But the spread of agriculture from its Middle Eastern cradle into the farthest reaches of Europe does not, as some researchers once thought, seem to have been accompanied by a mass movement of Middle Eastern farmers.

The coming together of two groups of humans can be seen in modern India, too. In the south of the subcontinent, people have Y-chromosomes derived almost exclusively from what the Cambridge school would interpret as being northern folk (and the Oxford school as the western survivors of Toba). However, more than 20% of their mitochondria arrived in Asia with the first migration from Africa (or, according to taste, clung on along the south-eastern fringes of the ash plume).

That discovery speaks volumes about what happened when the two groups met. It suggests that many modern south Indians are descended from southern-fringe women, but few from southern-fringe men—implying a comprehensive conquest of the southerners by the northerners, who won extra southern wives.

This observation, in turn, helps explain why Y-chromosome Adam lived so much more recently than mitochondrial Eve. Displacement by conquest is one example of a more general phenomenon—that the number of offspring sired by individual males is more variable than the number born by individual females. This means that more males than females end up with no offspring at all. Male gene lines therefore die out faster than female ones, so those remaining are more likely, statistically, to converge in the recent past.

Successful male gene lines, though, can be very successful indeed. Students of animal behaviour refer to the top male in a group as the "alpha". Such dominant animals keep the others under control and father a large proportion, if not all, of the group's offspring. One of the curiosities of modern life is that voters tend to elect alpha males to high office, and then affect surprise when they behave like alphas outside politics too. But in the days when alphas had to fight rather than scheme their way to the top, they tended to enjoy the sexual spoils more openly. And there were few males more alpha in their behaviour than Genghis Khan, a man reported to have had about 500 wives and concubines, not to mention the sexual opportunities that come with conquest. It is probably no coincidence, therefore, that one man in every 12 of those who live within the frontiers of what was once the Mongol empire (and, indeed, one in 200 of all men alive today) have a stretch of DNA on their Y-chromosomes that dates back to the time and birthplace of the great Khan.

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Meet the relatives

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A large and diverse family

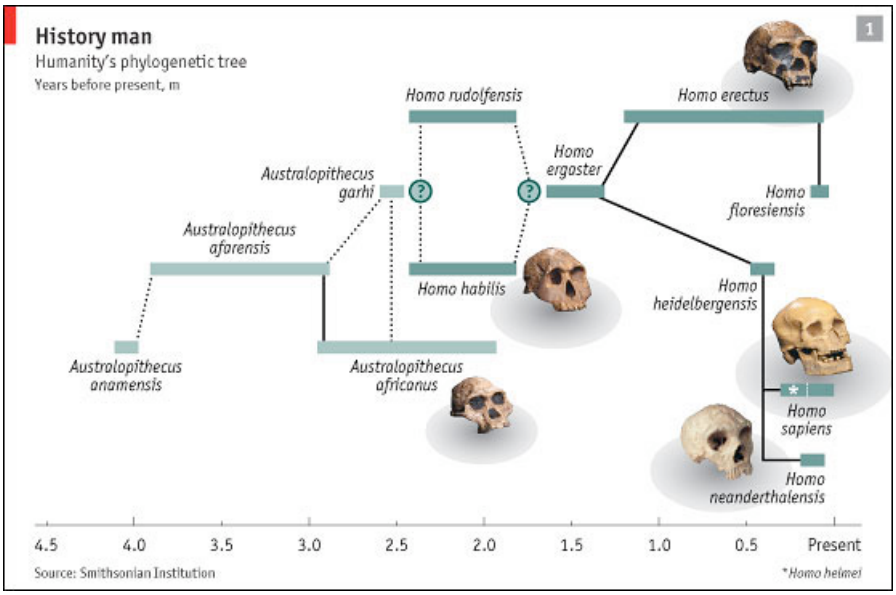
WHEN *Homo sapiens* emerged as a species, he was not alone. The world he entered was already peopled by giants and dwarfs, elves, trolls and pixies—in other words, creatures that looked humanlike, but were not the genuine article. Or, at least, not as genuine as *Homo sapiens* has come to believe himself to be.

Like the story of *Homo sapiens* himself, the story of the whole human family begins in Africa. About 4.5m years ago, probably in response to a drying of the climate that caused forest cover in that continent to shrink, one species of great ape found itself pushed out into the savannah, an ecological niche not normally occupied by apes. Over the next 300,000 years these apes evolved an upright stance. No one know for sure why, but one plausible explanation, advanced by Peter Wheeler of John Moores University in Liverpool, is that standing upright reduces exposure to sunlight. To an animal adapted to the forest's shade, the remorseless noonday sun of the savannah would have been a threat. Dr Wheeler's calculations suggest that walking upright decreases exposure at noon by a third compared with going on all fours, since less of the body's surface faces the overhead sun. Humanity, in the form of *Australopithecus anamensis*, had arrived.

Australopithecines of various species lasted for over 3m years. But half-way through that period something interesting happened. One of them begat a species known to science variously as *Homo rudolfensis* and *Homo habilis*. All modern great apes make tools out of sticks and leaves to help them earn their living, and there is no reason to believe that this was not true of australopithecines. But, aided by hands that no longer needed to double as part-time feet, *Homo habilis* began to exploit a new and potent material that needs both precision and strength to work—stone. This provided its immediate descendants with a powerful technology, but also gave its distant descendants in human palaeontology laboratories an additional way of tracing their ancestry, for stone tools often survive where bones do not.

Homo habilis's successor species, *Homo erectus*, did not bestride the globe in the way that his eventual descendant *Homo sapiens* did, but he certainly stuck his nose out of Africa. Indeed, the first fossil *erectus* discovered was in Java, in 1891, and the second one, several decades later, turned up in China, near Beijing. It was not until 1960 that *erectus* bones were found in Africa.

Homo erectus is a frustrating species. His tools are found all over the southern half of Eurasia, as well as in Africa. But China and Java aside, his bones are scarce outside Africa. There are two skullcaps from Georgia and half of one from India. He did, however, leave lots of descendants.

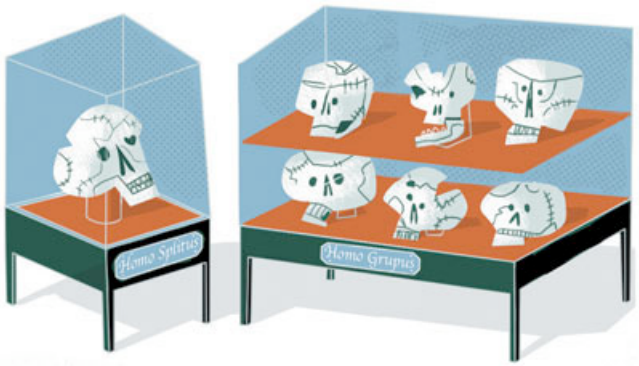


Naming fossils is a game that beautifully illustrates Henry Kissinger's witticism about academic disputes being so bitter because the stakes are so low. The best definition of a species that biologists have been able to come up with is "a group of creatures capable of fertile interbreeding, given the chance", which clearly makes it hard to determine what species a particular fossil belongs to. Researchers therefore have to fall back on the physical characteristics of the bones they find. That allows endless scope for argument between so-called splitters, who seem to want to give a new name to every skull discovered, and lumpers, who like to be as inclusive as possible.

Some splitters, for example, argue that the African version of *Homo erectus* should be called *Homo ergaster*. Whatever the niceties, it is clear that by 500,000 years ago, if not before, *Homo erectus* was breaking up into anatomically different populations. Splitters would like to turn the Georgia fossils, an early twig of the *erectus* tree, into *Homo georgicus*. There is also *Homo rhodesiensis*, found in southern Africa, *Homo heidelbergensis* from Europe, and a whole drawer's-worth of specimens known to some as *Homo helmei* and to others as archaic *Homo sapiens*.

How little is really known, though, was thrown into sharp relief by the announcement just over a year ago that yet another species, *Homo floresiensis*, had been found. It was discovered on Java's nearish neighbour island, Flores. Finding a new species of human is always exciting, but what is particularly intriguing about *Homo floresiensis* is how small it was—barely a metre tall when fully grown. Perhaps inevitably, though to the disgust of its discoverers, *Homo floresiensis* became known to journalists as the hobbit, after J.R.R. Tolkien's fictional humanoid. *Homo neanderthalensis*, the descendant of *Homo heidelbergensis*, by contrast, was

if not a giant then at least a troll. Though he stood five or ten centimetres shorter than a modern European *Homo sapiens*, the thickness of his bones suggests he was a lot heavier.



Both *Homo neanderthalensis* and *Homo floresiensis* were certainly around when *Homo sapiens* left Africa—whichever version of that story turns out to be the correct one. There may also have been some lingering populations of other hominid species. That raises the intriguing question of what happened when these residents met the *sapiens* wave.

Some researchers believe there was interbreeding, echoing the ideas of an older school of palaeoanthropology called multiregionalism. The multiregionalists thought either that pre-*sapiens* hominids were all a vast, interbreeding species that gradually evolved into *sapiens* everywhere, or, against all Darwinian logic, that *Homo sapiens* arose independently in several places by some unknown process of parallel evolution.

As recently as 2002, Alan Templeton, then at the University of Washington at St Louis, claimed to have found a number of genetic trees whose roots were 400,000-800,000 years old, and yet which included non-Africans. That, if confirmed, would support multiregionalism. Meanwhile, John Relethford, of the State University of New York's campus at Oneonta, has criticised the conclusions of studies on mitochondrial DNA extracted from the bones of Neanderthals. This does not resemble DNA from any known modern humans, which led the authors of the work to conclude there was no interbreeding. Dr Relethford points out that Neanderthal DNA brought into the *sapiens* population by interbreeding could subsequently have been lost by chance in the lottery of who does and who does not reproduce. Similar losses are known to have happened in Australia, where mitochondrial DNA from human fossils is absent from modern Australians.

Most students of the field, though, think there was no interbreeding, full stop. Either *Homo sapiens* persecuted his cousins into extinction or, with his superior technology, he outhunted, outgathered and outbred them. The next question is where that technology—or, rather, the brainpower to invent and make it—came from.

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If this is a man

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Why it pays to be brainy

THANKS to Dr Cann and her successors, the story of how *Homo sapiens* spread throughout the world is getting clearer by the day. But why did it happen? What was it that gave the species its edge, and where did it come from? Here, the picture blurs.

Until recently, it was common to speak of an Upper Palaeolithic revolution in human affairs—what Jared Diamond, of the University of California at Los Angeles, called the Great Leap Forward. Around 40,000 years ago, so the argument ran, humanity underwent a mental step-change. The main evidence for this was the luxuriant cave art that appeared in Europe shortly after this time. Palaeopsychologists see this art as evidence that the artists could manipulate abstract mental symbols—and so they surely could. But it is a false conclusion (though it was widely drawn before Dr Cann's work) that this mental power actually evolved in Europe. Since all humans can paint (some, admittedly, better than others), the mental ability to do so, if not the actual technique, must have emerged in Africa before the first emigrants left. Indeed, evidence of early artistic leanings in that continent has now turned up in the form of drilled beads made of shells and coral, and—more controversially—of stones that have abstract patterns scratched on to them and bear traces of pigment.

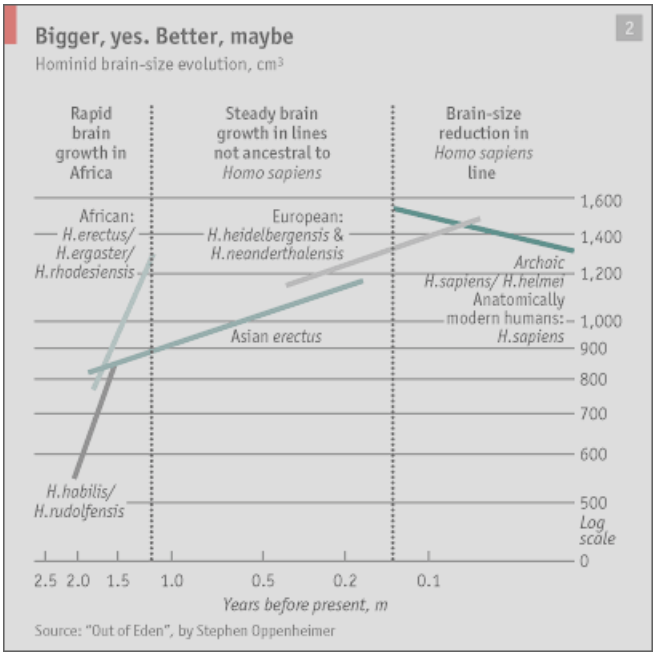
That certainly pushes the revolution back a few tens of millennia. The oldest beads seem to date from 75,000 years ago, and an inspired piece of lateral thinking suggests that clothing appeared at about the same time. Mark Stoneking and his colleagues at the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, applied the molecular-clock technique to human lice. They showed that head lice and body lice diverged 75,000 years ago. Since body lice live in clothing, and most other species of mammal support only one species of louse, the inference is that body lice evolved at the same time as clothes.

That is an interesting coincidence, and some think it doubly interesting that it coincides with

the eruption of Toba. It may be evidence of a shift of thought patterns of the sort that the Upper Palaeolithic revolutionaries propose. On the other hand, there are also signs of intellectual shifts predating this period. Sally McBrearty, of the University of Connecticut, and Alison Brooks, of George Washington University, have identified 14 traits, from making stone blades to painting images, which they think represent important conceptual advances. Ten of them, including fishing, mining, engaging in long-distance trade and making bone tools, as well as painting and making beads, seem to be unique to modern *Homo sapiens*. However, four, including grinding pigments (for what purpose remains unknown, but probably body painting), stretch back into the debatable past of *Homo helmei*.

Given the fragmentary nature of the evidence from Africa, which has not been explored with the same sort of archaeological fine-tooth comb as Europe, the speed of the emergence of modern behaviour is still debatable. One thing, however, that clearly played no part in distinguishing *Homo sapiens* from his hominid contemporaries was a bigger brain.

Modern people do, indeed, have exceedingly large brains, measuring about 1,300 cm^3. Other mammals that weigh roughly the same as human beings—sheep, for example—have brains with an average volume of 180cm^3. In general, there is a well-established relationship between body size and brain size that people very much do not fit. But as Dr Oppenheimer shows (see chart 2), most of this brain expansion happened early in human evolutionary history, in *Homo habilis* and *Homo erectus*. The brains of modern people are only about 6% larger than those of their immediate African predecessors. Perhaps more surprisingly, they are smaller than those of Neanderthals. There is no doubt that this early brain growth set the scene for what subsequently happened to *Homo sapiens*, but it does not explain the whole story, otherwise *Homo erectus* would have built cities and flown to the moon.



Flying to the moon may, in fact, be an apt analogy. Just as a space rocket needs several stages to lift it into orbit, so the growth of human intelligence was probably a multi-stage process, with each booster having its own cause or causes. What those causes were, and when they operated, remains a matter of vehement academic dispute. But there are several plausible hypotheses.

The most obvious idea—that being clever helps people to survive by learning about their surroundings and being able to solve practical problems—is actually the least favoured explanation, at least as the cause of the Great Leap Forward. But it was probably how intelligence got going in the pre-human primate past, and thus represented the first stage of the rocket.

Many primates, monkeys in particular, are fruit-eaters. Eating fruit is mentally taxing in two ways. The first is that fruiting trees are patchily distributed in both space and time (though in the tropics, where almost all monkeys live, there are always trees in fruit somewhere). An individual tree will provide a bonanza, but you have to find it at the right moment. Animals with a good memory for which trees are where, and when they last came into fruit, are likely to do better than those who rely on chance. Also, fruit (which are a rare example of something that actually *wants* to be eaten, so that the seeds inside will be scattered) signal to their consumers when they are ready to munch by changing colour. It is probably no coincidence, therefore, that primates have better colour vision than most other mammals. But that, too, is heavy on the brain. The size of the visual cortex in a monkey brain helps to explain why monkeys have larger brains than their weight seems to warrant.

The intelligence rocket's second stage was almost certainly a way of dealing with the groups that fruit-eating brought into existence. Because trees in the tropics come into fruit at random, an animal needs a lot of fruit trees in its range if it is to avoid starving. Such a large range is difficult for a lone animal to defend. On the other hand, a tree in fruit can feed a whole troop. For both these reasons, fruit-eating primates tend to live in groups.

But if you have to live in a group, you might as well make the most of it. That means avoiding conflict with your rivals and collaborating with your friends—which, in turn, means keeping track of your fellow critters to know who is your enemy and who your ally. That, in turn, demands a lot of brain power.

One of the leading proponents of this sort of explanation for intelligent minds is Robin Dunbar, of Liverpool University in England. A few years ago, he showed that the size of a primate's brain, adjusted for the size of its body, is directly related to the size of group it lives in. (Subsequent work has shown that the same relationship holds true for other social mammals, such as wolves and their kin.) Humans, with the biggest brain/body ratio of all, tend to live in groups of about 150. That is the size of a clan of hunter-gathers. Although the members of such a clan meet only from time to time, since individual families forage separately, they all agree on who they are. Indeed, as Dr Dunbar and several other researchers have noticed, many organisations in the modern world, such as villages and infantry companies, are about this size.

Living in collaborative groups certainly brings advantages, and those may well offset the expense of growing and maintaining a large brain. But even more advantage can be gained if an animal can manipulate the behaviour of others, a phenomenon dubbed Machiavellian intelligence by Andrew Whiten and Richard Byrne, of the University of St Andrews in Scotland.

Size isn't everything

Monkeys and apes manage this to a certain extent. They seem to have a limited "theory of mind"—the ability to work out what others are thinking—which is an obvious prerequisite for the would-be simian politician. They also engage in behaviour which, to the cynical human zoologist, looks suspiciously like lying. But it is those two words, "cynical" and "suspiciously", that give the game away. For it is humans themselves, with their ability to ponder not only what others are thinking, but also what those others are thinking about them, who are the past masters of such manipulation.

And it is here that the question of language enters the equation. Truly Machiavellian manipulation is impossible without it. And despite claims for talking chimpanzees, parrots and dolphins, real language—the sort with complex grammar and syntax—is unique to *Homo sapiens*.

Dr Dunbar's hypothesis is that language arose as a substitute for the physical grooming that other group-living primates use to maintain bonds of friendship. Conversation—or gossip, as he refers to it—certainly does seem to have the same bond-forming role as grooming. And, crucially for the theory, groups rather than just pairs can "groom" each other this way. Dr Dunbar sees the 150-strong group size of *Homo sapiens* as both a consequence and a cause of verbal grooming, with large groups stimulating the emergence of language, and language then permitting the emergence of larger groups still. Language, therefore, is the result of a process of positive feedback.

Once established, it can be deployed for secondary purposes. Furthering the Machiavellian ends outlined by Dr Whiten and Dr Byrne would be one such purpose, and this would drive other feedback loops as people evolve more and more elaborate theories of mind in order to manipulate and avoid manipulation. But language would also promote collaborative activities such as trade and the construction of sophisticated artefacts by allowing specialisation and division of labour.

Not everyone agrees with the details of this thesis, but the idea that the evolution of mental powers such as language has been driven by two-way feedback loops rather than one-way responses to the environment is a powerful one. Terrence Deacon, a researcher at the University of California at Berkeley, for instance, thinks that language evolved in a feedback loop with the complex culture that it allowed humans to create. Changes in culture alter and complicate the environment. Natural selection causes evolutionary changes that give people the means to exploit their new, more complex circumstances. That makes the cultural environment still more complicated. And so on. Dr Deacon believes this process has driven the capacity for abstract thought that accounts for much of what is referred to as intelligence. He sees it building up gradually in early hominids, and then taking off spectacularly in *Homo sapiens*.

The peacock mind

Perhaps the most intriguing hypothesis about the last stage of the mental-evolution rocket, though, is an idea dreamed up by Geoffrey Miller, of the University of New Mexico. He thinks that the human mind is like a peacock's tail, a luxuriant demonstration of its owner's genetic fitness.

At first sight this idea seems extraordinary, but closer examination suggests it is disturbingly plausible. Lots of features displayed by animals are there to show off to the opposite sex. Again, this involves a feedback loop. As the feature becomes more pronounced, the judge becomes more demanding until the cost to the displayer balances the average reproductive benefit.

Frequently, only one sex (usually the male) does the showing off. That makes the sexually selected feature obvious, because it is absent in the other sex. Dr Miller, though, argues that biologists have underplayed the extent to which females show off to males, particularly in species such as songbirds where the male plays a big part in raising the young, and so needs to be choosy about whom he sets up home with. Like male birds, male humans are heavily involved in childrearing, so if the mind is an organ for showing off, both sexes would be expected to possess it—and be attracted by it—in more or less equal measure.

Dr Miller suggests that many human mental attributes evolved this way—rather too many, according to some of his critics, who think that he has taken an interesting idea to implausible extremes. But sexual selection does provide a satisfying explanation for such otherwise perplexing activities as painting, carving, singing and dancing. On the surface, all of these things look like useless dissipations of energy. All, however, serve to demonstrate physical and mental prowess in ways that are easy to see and hard to fake—precisely the properties, in fact, that are characteristic of sexually selected features. Indeed, a little introspection may suggest to the reader that he or she has, from time to time, done some of these things to show off to a desirable sexual partner.

Crucially, language, too, may have been driven by sexual selection. No doubt Machiavelli played his part: rhetoric is a powerful political skill. But seduction relies on language as well, and encourages some of the most florid speech of all. Nor, in Dr Miller's view of the world, is the ability to make useful things exempt from sexual selection. Well-made artefacts as much as artful decorations indicate good hand-eye co-ordination and imagination.

Whether Dr Miller's mental peacock tails have an underlying unity is unclear. It could be the ability to process symbols; or it could be that several different abilities have evolved independently under a single evolutionary pressure—the scrutiny of the opposite sex. Or it could be that sexual selection is not the reason after all, or at least not the main part of it. But it provides a plausible explanation for modern humanity's failure to interbreed with its Neanderthal contemporaries, whether or not such unions would have been fertile: they just didn't fancy them.

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The concrete savannah

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Evolution and the modern world

THE eruption of Toba marked the beginning rather than the end of hostilities between *Homo sapiens* and the climate. Views differ about whether the eruption was the trigger, but it is clear that an ice age started shortly afterwards. Though the species spread throughout Asia, Australia and Europe (the populating of the Americas is believed by most researchers to have happened after the ice began to retreat, although not everybody agrees), it was constrained by ecological circumstances in much the same way as any other animal. The world's population 10,000 years ago was probably about 5m—a long way from the imperial 6-billion-strong species that bestrides the globe today.

The killer application that led to humanity's rise is easy to identify. It is agriculture. When the glaciers began to melt and the climate to improve, several groups learned how to grow crops and domesticate animals. Once they had done that, there was no going back. Agriculture enabled man to shape his environment in a way no species had done before.

In truth, agriculture turned out to be a Faustian bargain. Both modern and fossil evidence suggests that hunter-gatherers led longer, healthier and more leisured lives than did farmers until less than a century ago. But farmers have numbers on their side. And numbers beget numbers, which in turn beget cities. The path from Catalhoyuk in Anatolia, the oldest known town, to the streets of Manhattan is but a short one, and the lives of people today, no matter how urbane and civilised, are shaped in large measure by the necessities of their evolutionary past.

That fact has, however, only recently begun to be widely recognised. For many years, psychology, like anthropology, operated in a strange intellectual vacuum. Psychologists did not

deny man's evolutionary past, but they did not truly acknowledge it, either. Many in the field seemed to feel that humanity had somehow transcended evolution. Indeed, those of a Marxist inclination more or less required that to be true. How else could people be perfectible? Dissenters were usually treated with disdain. But, at about the time that Dr Cann was publishing the work that would expose the fallacy of multiregionalism, a group who dubbed themselves "evolutionary psychologists" began to stick their heads above the academic parapets.

Eve's psyche

Studying the behaviour of humans is more difficult than studying that of other animals, for two reasons. One is that the students come from the same species as the studied, which both reduces their objectivity and causes them to take certain things for granted, or even fail to notice them altogether. The other is that human culture is, indeed, far more complex than the cultures of other species. There is nothing wrong with studying that culture, of course. It is endlessly fascinating. But it is wrong to assume that it is the cause of human nature, rather than a consequence; that is akin to mistaking the decorative finishes of a building for the underlying civil engineering. The aim of evolutionary psychology is to try to detect the Darwinian fabric through the cultural decoration, by asking basic questions.

Many of those questions, naturally, address sensitive issues of sex and violence—another reason evolutionary psychologists are not universally popular. David Buss, of the University of Texas, demonstrated experimentally what most people know intuitively—that women value high status in a mate in a way that men do not. Helen Fisher, of Rutgers University, has dissected the evolutionary factors that cause marriages to succeed or fail. She thinks, for example, that the tendency of females to prefer high-status mates is at odds with the increasing economic independence of women in the modern world. Laura Betzig, of the University of Michigan, put an explicitly Darwinian spin on the tendency of powerful men to accumulate harems.

Randy Thornhill, of the University of New Mexico, has shown that physical beauty is far from being in the eye of the beholder. In fact, those features rated beautiful, most notably bodily symmetry, are good predictors of healthy, desirable attributes such as strong immune systems—in other words, aesthetic sensibilities have evolutionary roots.

Karl Grammer, of the Ludwig Boltzmann Institute of Urban Ethology, in Vienna, has shown that body odour, too, is correlated with symmetry and linked to immunological strength. Dr Thornhill, meanwhile, has raised quite a few hackles by arguing that a propensity to rape is an evolved characteristic of men rather than a pathology. Even murder has not escaped the attention of the evolutionary psychologists. Martin Daly and Margo Wilson, of McMaster University in Hamilton, Ontario, showed that adults are far more likely to kill their stepchildren than their biological children—a fact that had escaped both police forces and sociologists around the world. They then dared to propose a Darwinian explanation for this, namely that step-parents have no direct interest (in the evolutionary sense) in the welfare of stepchildren.

However, something similar to this list of human behaviours that have yielded to evolutionary psychology could be found in many species. Indeed, it was often comparisons with other species that sparked the investigations in the first place. The males of many other species gather harems, but females rarely do so; female swallows prefer their mates to have symmetrical tails and they are also more faithful to high-status males; both male lions and male baboons kill the infants of females in groups they have just taken over; and so on. Where evolutionary explanations of behaviour become really interesting is when they home in on what is unique to humanity.

Playing games with the truth

One uniquely human characteristic is the playing of games with formal rules. Evolutionary psychology has not yet sought to explain this, but it has exploited it extensively to develop and test its ideas. In their different ways, the games devised by Leda Cosmides and John Tooby, of the University of California at Santa Barbara, and Robert Axelrod, of the University of Michigan, have underpinned that part of evolutionary psychology devoted to uniquely human behaviour. For not all games are about competition. Many also require trust, a sense of justice and sometimes self-denial.

Cases of animals apparently making sacrifices, occasionally of their own lives, to help others are not rare in nature, but at first sight they are surprising. What is in it for the sacrificer? The usual answer, worked out in the 1960s by William Hamilton, is that the beneficiary is a relative whose reproductive output serves to carry genes found in the sacrificer into the next generation, albeit at one remove. Translated into human terms, this is good old-fashioned nepotism. In a few species, though—mankind being the most obvious—people will make sacrifices for non-relatives, or "friends". The assumption is that the favour will be paid back at some time in the future. The question is, how can the sacrificer be sure that will happen?

Dr Axelrod used a branch of maths called game theory to come up with at least part of the answer. He showed mathematically that as long as you can recognise and remember your fellow creatures, it makes sense to follow the proverb "fool me once, shame on you; fool me twice, shame on me" and trust them provided they don't cheat you. (Sometimes in science it is necessary to prove the obvious before you go on to the less obvious.) Dr Cosmides and Dr Tooby used a different sort of game to show that humans are thus, as Dr Axelrod's model suggests they should be, acutely sensitive to unfair treatment. They did this by presenting some problems of formal logic to their experimental subjects as a card game. When the problems were presented using cards with letters and numbers on opposite faces, and the subjects had to work out which cards needed to be turned over to yield the required answers, people found them hard to do and more often than not got them wrong. However, when the problems were presented in a form that required the subjects to decide whether people were being treated fairly or not, they found them really easy. The researchers' conclusion is that humans are hard-wired not for logic but for detecting injustice.

Trust, and the detection and punishment of injustice, lie at the heart of human society. They are so important that people will actually harm their own short-term interests to punish those they regard as behaving unfairly. Another game, for example, involves two people dividing a sum of money ($100, say). One makes the division and the other accepts or rejects it. If it is rejected, neither player gets any money. On the face of it, even a 99:1 division should be accepted, since the second player will be one dollar better off. In practice, though, few people will accept less than a 70:30 split. They will prefer to punish the divider's greed rather than take a small benefit themselves.

This makes no sense in a one-off transaction, but makes every sense if the two participants are likely to deal with each other repeatedly. And that, before the agricultural population boom (and also, for the most part, after it) was the normal state of affairs. The people an individual dealt with routinely would have been the members of his circle of 150. Strangers would have been admitted to this circle only after prolonged vetting. Such bonds of trust, described by Matt Ridley, a science writer, as "the origins of virtue" in his book of that name, underlie the exchanges of goods and services that are the basis of economics. They may also, though, underlie another sensitive subject that social scientists do not like biologists treading on: race.

Robert Kurzban, a colleague of Dr Cosmides and Dr Tooby, took the racial bull by the horns by

reversing the old saw about beauty. Dr Thornhill's work overturned the folk wisdom that beauty is in the beholder's eye by showing that universal standards of beauty have evolved, and there are good reasons for them. Dr Kurzban, by contrast, thinks he has shown that race really does exist only in the eye—or, rather, the mind—of the beholder, not the biology of the person being beheld, and does so for good Darwinian reasons.

First impressions count

Dr Kurzban observes that the three criteria on which people routinely, and often prejudicially, assess each other are sex, age and race. Judgments based on sex and age make Darwinian sense, because people have evolved in a context where these things matter. But until long-distance transport was invented, few people would have come across members of other races. Dr Kurzban believes that perceptions of racial difference are caused by the overstimulation of what might be called an "otherness detector" in the human mind. This is there to sort genuine strangers, who will need to work hard to prove they are trustworthy, from those who are merely unfamiliar members of the clan. It will latch on to anything unusual and obvious—and there is little that is more obvious than skin colour. But other things, such as an odd accent, will do equally well. Indeed, Dr Dunbar thinks that the speed with which accents evolve demonstrates that they are used in precisely this sort of way.

If Dr Kurzban is right (and experiments he has done suggest that assessments of allegiance are easily "rebadged" away from skin colour by recognisable tokens such as coloured T-shirts, as any sports fan could probably have told him), it explains why race-perception is such a powerful social force, even though geneticists have failed to find anything in humans that would pass muster as geographical races in any other species. In fact, one of the striking things about *Homo sapiens* compared with, say, the chimpanzee is the genetic uniformity of the species. The only "racial" difference that has a well-established function is skin colour. This balances the need to protect the skin from damage by ultraviolet light (which requires melanin, the pigment that makes skin dark) and the need to make vitamin D (which results from the action of sunlight on a chemical in the skin). This explains dark, opaque skins in the tropics and light, transparent ones nearer the poles. The test is that dark-skinned arctic dwellers, such as the Inuit of North America, have diets rich in vitamin D, and so do not need to make it internally. As to other physical differences, they may be the result of founder effects, as described by Dr Ambrose, or possibly of sexual selection, which can sometimes pick up and amplify arbitrary features.

Darwinian thinking can lead in other unexpected directions, too. Pursue Dr Buss's observation about women preferring high-status males to its logical conclusion, and you have a plausible explanation for the open-endedness of economic growth. Psychologists of a non-evolutionary bent sometimes profess themselves puzzled by the fact that once societies leave penury behind (the cited income level varies, but $10,000 per person per year seems about the mark), they do not seem to get happier as they get richer.

That may be because incomes above a certain level are as much about status as about material well-being. Particularly if you are a man, status buys the best mates, and frequently more of them. But status is always relative. It does not matter how much you earn if the rest of your clan earn more. People (and men, in particular) are always looking for ways to enhance their status—and a good income is an excellent way of doing so. Aristotle Onassis, a man who knew a thing or two about both wealth and women, once said: "If women didn't exist, all the money in the world would have no meaning." Perhaps the founding father of economics is not really Adam Smith, who merely explained how to get rich, but Charles Darwin, who helped to explain why.

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Starchild

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Evolution is still continuing

WHAT, then, of the future? Sitting in the comfort of the concrete savannah, has humanity stopped evolving?

To help answer that question, it is instructive to look at a paper published earlier this year by Gregory Cochran. Dr Cochran, a scientist who, in the tradition of Darwin himself, works independently of an academic institution, looked at the unusual neurological illnesses commonly suffered by Ashkenazi Jews. Traditional wisdom has it that these diseases, which are caused by faulty genes, are a consequence of inbreeding in a small, closed population. The fact that they persist is said to show that human evolution has stopped in our ever more mollycoddled and medicalised world. Dr Cochran begged not only to differ, but to draw precisely the opposite conclusion. He sees these diseases as evidence of very recent evolution.

Until a century or two ago, the Ashkenazim—the Jews of Europe—were often restricted by local laws to professions such as banking, which happened to require high intelligence. This is the sort of culturally created pressure that might drive one of Dr Deacon's feedback loops for mental abilities (though it must be said that Dr Deacon himself is sceptical about this example). Dr Cochran, however, suspects that this is exactly what happened. He thinks the changes in the brain brought about by the genes in question will be shown to enhance intelligence when only one copy of a given disease gene is present (you generally need two copies, one from each parent, to suffer the adverse symptoms). Indeed, in the case of Gaucher's disease, which is not necessarily lethal, there is evidence that sufferers are more

intelligent than average. If Ashkenazi Jews need to be more intelligent than others, such genes will spread, even if they sometimes cause disease.

The fact is, you can't stop evolution. Those who argue the opposite, pointing to the survival thanks to modern medicine of people who would previously have died, are guilty of more than just gross insensitivity. They have tumbled into an intellectual pitfall that has claimed many victims since Darwin first published his theory. Evolution is not about progress. It is about adaptation. Sometimes adaptation and progress are the same. Sometimes they are the opposite. (Ask a tapeworm, which has "degenerated" into a mere egg-laying machine by a very successful process of adaptation.) If a mutation provides a better adaptation, as Dr Cochran thinks these disease genes did in financiers, it will spread. Given the changes that humanity has created in its own habitat, it seems unlikely that natural selection has come to a halt. If Dr Deacon is right, it may even be accelerating as cultural change speeds up, although the current rapid growth in the human population will disguise that for a while, because selection works best in a static population.

The next big thing

Evolution, then, has not stopped. Indeed, it might be about to get an artificial helping hand in the form of genetic engineering. For the fallacy of evolutionary progress has deep psychological roots, and those roots lie in Dr Miller's peacock-tail version of events. The ultimate driver of sexual selection is the need to produce offspring who will be better than the competition, and will thus be selected by desirable sexual partners. Parents know what traits are required. They include high intelligence and a handful of physical characteristics, some of which are universal and some of which vary according to race. That is why, once the idea of eliminating disease genes has been aired, every popular discussion on genetic engineering and cloning seems to get bogged down in intelligence, height and (in the West) fair hair and blue eyes.

This search for genetic perfection has an old and dishonourable history, of course, starting with the eugenic movement of the 19th century and ending in the Nazi concentration camps of the 20th, where millions of the confrères of Dr Cochran's subjects were sent to their deaths. With luck, the self-knowledge that understanding humanity's evolution brings will help avert such perversions in the future. And if genetic engineering can be done in a way that does not harm the recipient, it would not make sense to ban it in a liberal society. But the impulse behind it will not go away because, progressive or not, it is certainly adaptive. Theodosius Dobzhansky, one of the founders of genetics, once said that "nothing in biology makes sense except in the light of evolution". And that is true even of humanity's desire to take control of the process itself.

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Acknowledgment and sources

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The author would like to acknowledge the help of the numerous researchers named in the text. The following books and website may be of interest to readers who wish to learn more about the subject.

"Out of Eden", by Stephen Oppenheimer (Constable and Robinson, paperback)

"The Journey of Man", by Spencer Wells (Penguin, paperback)

"From Lucy to Language", by Donald Johanson and Blake Edgar (Weidenfeld and Nicolson)

"Grooming, Gossip and the Evolution of Language", by Robin Dunbar (Faber and Faber, paperback)

"The Symbolic Species", by Terrence Deacon (W.W. Norton)

"The Mating Mind", by Geoffrey Miller (William Heinemann)

"The Origins of Virtue", by Matt Ridley (Penguin, paperback)

http://www.nationalgeographic.com/genographic

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Author interview

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From Economist.com

A discussion with Geoffrey Carr, Science Editor of *The Economist*

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