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Stones and bones can only tell us so much, but living primates hold a wealth of untapped knowledge about what our ancestors were like, says **Dan Jones**

A window on the past

DAYBREAK, and a group of apes are dancing around a rectangular monolith so dark it seems to suck light in. Inspired by this mysterious object, one of them grabs a bone and begins to wield it as a tool – then as a weapon. The armed ape goes hunting, makes a kill and eats flesh for the first time. Next day, he drives a rival group of apes from a watering hole and murders their leader. This, according to Stanley Kubrick's sci-fi masterpiece *2001: A space odyssey*, is the dawn of humankind.

If only it were that simple. Anyone trying to understand our origins soon realises that no one thing pushed our ape ancestors across the threshold of humanity. It is difficult to pin down what makes us human anyway. We walk upright on two legs, with disproportionately large brains held high, communicating in spoken languages, navigating the complexity of human social life, producing sophisticated tools and artefacts, and creating culture. The story of how we became human is woven from many strands.

Attempts to unravel that tale have until recently relied on the hard evidence of fossilised bones. This has allowed us to make inferences about certain aspects of our ancestors: how big they were, how they moved and their cranial capacity. But there is a limit to what you can learn from bones. In particular, they tell us little about our ancestors' less tangible traits, such as how fast they grew, their age at weaning and sexual maturity, and how many offspring they had. They also tell us almost nothing about thought and behaviour. This is a problem, says Robin Dunbar of the University of Oxford, because such factors are important in human evolution. "They're all part of the big story."

To get a handle on when and how humans developed these traits, some researchers are turning to information of a different kind. They are looking at living primates in the hope of discovering general rules governing how these animals' anatomy, ecology, life history and behaviours are linked. By taking such rules and applying them to our fossil ancestors, they hope to learn more than the bare bones alone can reveal. "We're trying to flesh out the social, behavioural and cognitive contexts that those bones are wrapped in," says Dunbar.

Reasonably enough, Dunbar and his colleagues Amanda Korstjens and Julia Lehmann at the University of Liverpool, UK, have focused their study on our closest living relatives, the chimpanzees. It turns out, for example, that the size of the groups in which chimps live is related to local climate, which affects the food available. Group size can be tied to three key climatic factors: mean temperature, annual rainfall and fluctuations in climate over the year. In turn, group size has a bearing on other aspects of chimpanzee life. The first is ecological: as groups get bigger, individuals have to spend more time, and roam further, to get enough food to feed the group. The second is social: bigger groups mean more social bonds to maintain, which translates to more time spent grooming one another (*Evolutionary Ecology*, vol 21, p 613).

Dunbar and his Oxford colleague Caroline Bettridge are now applying what they have learned about chimps to our early ancestors the australopithecines. This group of hominins, consisting of around half a dozen species, lived in Africa between 3.5 and 1.8 million years ago, when the climate was generally warmer than now. Dunbar and Bettridge's study is based on 68 sites at which fossilised remains have been found. Information about climate at these sites – and hence likely group size – can be gleaned from geological formations and the fossilised plants and animals they contain. Another indicator of group size comes from measuring the cranial volume of the fossils: larger brains seem to correlate with bigger group size, reflecting the cognitive capacity required to maintain complex social networks. Based on fossil remains, australopithecines probably had the brainpower to live in groups of up to 70 individuals.

With this information, the researchers have started to make educated guesses about australopithecine behaviour. It seems unlikely that they roamed and foraged in the same way as modern chimps. "If their ecology had been like that of chimpanzees, they would have been hard pressed to survive in most of the places that we know from the fossil record they did in fact occupy," Dunbar says. In › their hot open homelands, they would have had to spend too much time on the move to feed themselves. "We can then ask which parameter values need to be tweaked to 'get them to live' in the habitats we know they lived in, and not in those we know they didn't."

The tweak may be that australopithecines were able to move more rapidly than previously thought. Alternatively, it could be a more fluid group structure: small groups move more quickly, so it is possible that large bands of australopithecines split into smaller parties when on the move. A more radical suggestion is that australopithecines might have been able to reduce their foraging time by changing from a herbivorous diet to one containing meat, which is more calorific – a shift that is generally thought to have taken place later in human evolution.

> **"We are now applying what we have learned about chimps to our early ancestors"**

This is a work in progress. Dunbar needs more data from species such as baboons to clarify which aspects of australopithecine behaviour need to be tweaked to fit their environment. "Once we've done that, the objective is to do the same sort of analysis throughout the hominins," Dunbar says.

Michael Plavcan from the University of Arkansas in Fayetteville is adopting a related approach. His starting point is the relatively low level of sexual dimorphism – that is, the physical differences between males and females – that we see in the size of humans today. "People have tended to assume that species that are very dimorphic must live in polygamous systems, and those that are not must be monogamous," says Plavcan. Male gorillas, which are much bigger than females, can monopolise the members of their harem and must defend their patch from rival males. By contrast, pair-bonded species such as gibbons show little or no difference in size. On the basis of such differences, humans' limited sexual dimorphism in size, amounting to about 10 per cent of body weight, has conventionally been taken as a sign that we are a species that is naturally quite monogamous.

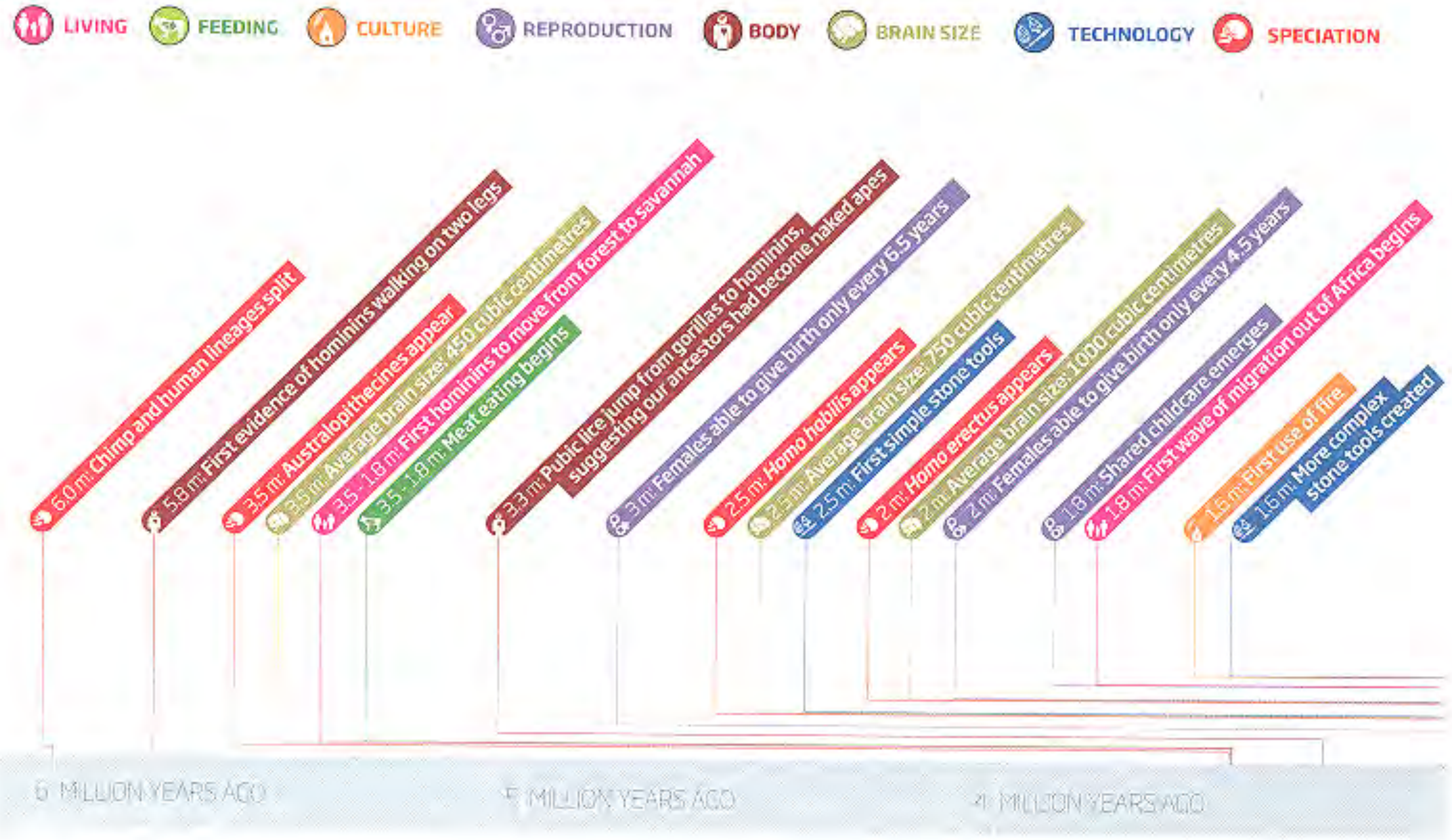
However, as dimorphism and sexual behaviour are assessed in more primate species, the picture has become less clear (*American Journal of Physical Anthropology*, vol 116, p 25). "Dimorphism is complicated," says Plavcan. Species that have big differences in size between males and females are usually polygamous, he says, but smaller differences do not necessarily mean monogamy. Despite this, Plavcan reckons size dimorphism can yield important clues about the process of becoming human.

The fossil record indicates that around 6 million years ago, just after the split with chimp ancestors, the size difference between male and female human ancestors was substantial: greater than that seen in modern chimpanzees, though less than in gorillas. Size dimorphism then gradually decreased as females became larger while males stayed around the same size, until modern size differences appeared with *Homo erectus* around 2 million years ago. This, Plavcan says, suggests something interesting was going on. In most primate groups, when females get bigger, males tend to follow suit. Why didn't our ancestors follow this pattern?

Plavcan points out that size dimorphism can only persist if the biggest males can monopolise females and so pass on their genes at the expense of smaller males. That cycle can be broken if females change their behaviour in a way that makes it more difficult

Becoming human

The evolution of us in 34 short chapters



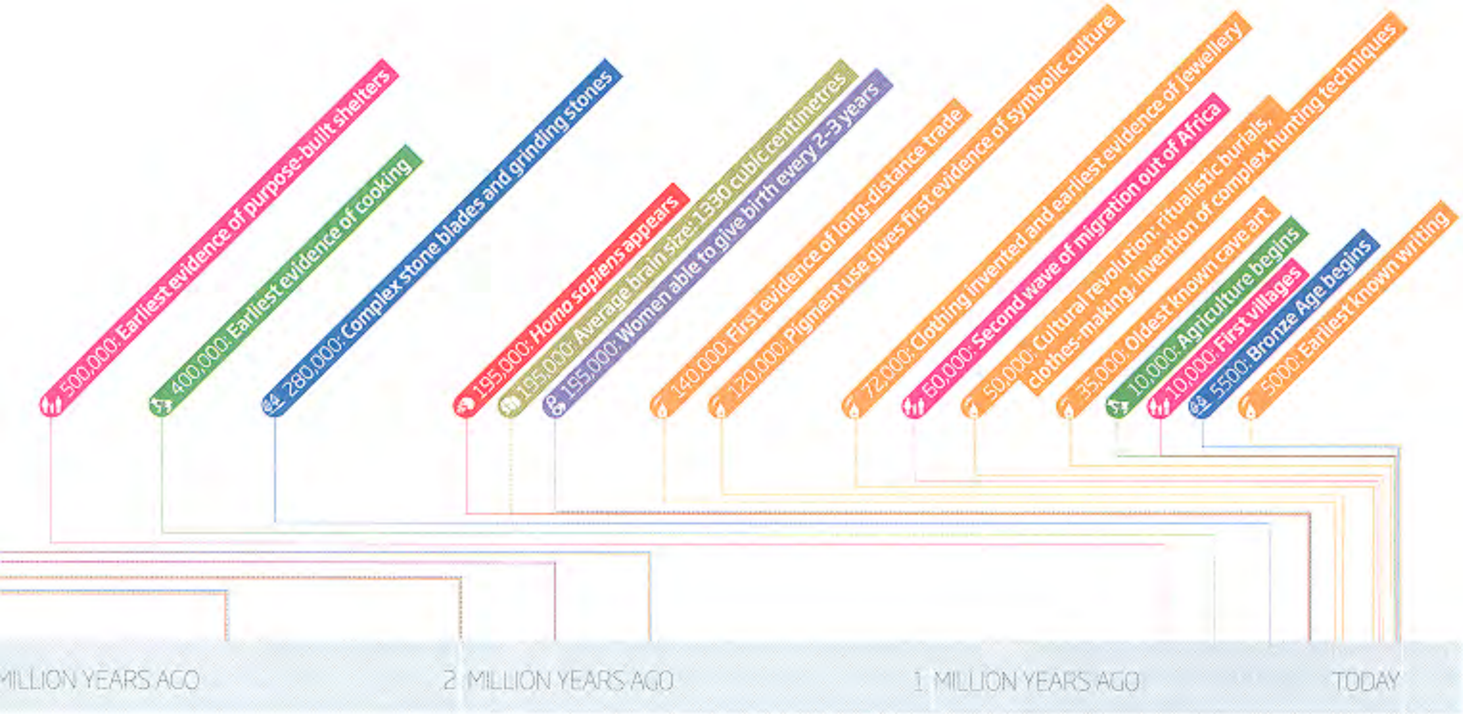
CYRIL RUOSSO/JH EDITORIAL/MINDEN

What's 6 million years between close relatives?

for a single male to monopolise them. If that happens, more males become able to pass on their genes, reducing competition for females and removing some of the pressure to be big, leading to a reduction in size dimorphism. The decreasing size differences of our ancestors "tells us that the way females behave is changing", Plavcan says.

But how? One possibility is a shift in foraging behaviour led by a change in the availability of food. When food sources are patchy, groups of females tend to cluster around them, making it easier for dominant males to monopolise the females. When resources are spread out more widely, this is not so easy. Then the reproductive success of a male becomes tied to that of individual female partners: if she doesn't survive and thrive, she can't bear his offspring.

Once a connection between male and female reproductive success is forged, the pressures for males to be big relax, argues Plavcan. That could be what happened to narrow human size differences. ›



PENNY TWEEDIE/CORBIS

Australopithecus skulls give clues to the sizes of their groups

JOHN READER/SPL

Yet this is not the only explanation on the table. A seemingly unrelated fact of our evolutionary history – the ever-expanding brain – may hold part of the answer too.

Big brains have benefits, but they come at a price. They are metabolically expensive to run, and building them demands not only a lot of energy but also significant nurturing. These costs hit where it hurts: in the currency of reproductive success. Another comparative analysis drives home the point. When Karin Isler and Carel van Schaik from the University of Zurich, Switzerland, surveyed 1247 animal species, including some primates, they found that in general the bigger the brain relative to body size, the less fecund the species.

"Babies are helpless when born and demand massive parental investment, yet humans are highly fecund"

This leaves humans in an odd position. Human babies are helpless when born, take a long time to grow and reach independence, and demand massive parental investment. Yet humans are highly fecund: in hunter-gatherer societies without modern birth control, the interval between births is around two to three years, compared with five years in chimps and eight in orang-utans.

There are other exceptions to the rule that big brains equal low fecundity. Large-brained birds such as owls and woodpeckers are often blind when they hatch and always require lots of nurturing, yet produce chicks as frequently as their smaller-brained relatives (*Biology Letters*, vol 5, p 125). The same combination of large brains and high fecundity is also found in wolves, foxes, coyotes and jackals. The common factor is allomaternal care, where mothers raising young can call on help from others, including fathers, older offspring or even unrelated individuals.

By virtue of their demanding brains, human children also require input from both parents to maintain reproductive rates, which ties the reproductive interests of males and females together. This outcome is the same as that of Plavcan's end-of-the-harem model, but the causes are different. Which explanation is correct? "If dimorphism is lost before infants needed a lot more care, it would be a purely behavioural ecological model that explains the loss," says Plavcan. "If they need a lot of care and then the dimorphism is lost, that would suggest that there is a change in the degree of maternal care that might factor into the reduction in dimorphism."

So when did the hominin brain become so large that shared care was essential if high fecundity was to be maintained? Isler and van Schaik calculate that for australopithecines 3 million years ago the inter-birth interval was around 6.5 years, decreasing to around 4.5 years by 2 million years ago as *H. erectus* was emerging, and to something comparable to today's hunter-gatherer societies from about 1 million years ago. "We calculated that allomaternal care is required once adult brain size reaches about 1000 cubic centimetres, or about *Homo erectus* size," says Isler. Above this size, ape-like caring systems cannot sustain reproductive output at a level to keep the species viable, and it would be likely to die out, she argues.

So can we now be confident that allomaternal care emerged in our ancestors somewhere between 1.5 and 2 million years ago? Not quite. "Our calculations of inter-birth intervals are rather rough," Isler admits. "And the estimate of a 'grey ceiling' of 1000 cubic centimetres, beyond which a traditional ape-like childcare style would not be feasible, is based on some assumptions that are not easy to test, such as infant mortality rates in extinct species." Plavcan is even more cautious, given that the deductions made from studying living primates have yet to be corroborated with fossil evidence. "The fossil record is thin on this issue," he says. While there could well be a link between brain size, child care and dimorphism, he recognises that we cannot be sure about the chronology without stronger evidence of the cranial capacity of *H. erectus*.

If even the proponents of using living species to gain insights into our evolutionary past are so cautious, where does that leave the endeavour? "There's so much variability, even between different populations of the same species, that it's difficult to draw any firm conclusions," says anthropologist Nicholas Malone at the University of Notre Dame in Indiana, who has also used this approach. "The more data we collect, the more we realise how difficult it is to make direct inferences about ape sociality, because there is so much flexibility in what they do."

Others take a more pragmatic view. They recognise that living species are the only real source of insight into human evolution beyond the stones and bones our ancestors left behind. "I think what's changing is what we can predict and the kinds of inferences we can make," says Plavcan. Dunbar agrees. "We're now in a position to make more of the fossil record, partly because we now know so much more about the behaviour of humans and primates." ■

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KELLY HARRIS/GETTY

> "There is a perception that art and science are opposed, but they should be complementary"

"You can't tell anything from pigment analysis. It's too broad. You don't know enough about what everybody else was doing at the time."

PPB: In the documentary *Who the #$&% is Jackson Pollock?* a New York art lawyer questions the relevance of fingerprint evidence. I think that says it all. I grew up with art and I think intuition is absolutely relevant, because in the end how a painting looks is subjective. A person has to develop a language of seeing, a visual vocabulary, to articulate what he sees when he looks at art. The trouble is, even the highly visually aware can be fooled, and that's where our techniques come in. Ideally, the two approaches are complementary.

Despite its resistance, the art world has come to rely on you, hasn't it?

PPB: The provenance of a painting has always been important in the buying and selling of art. But faking a provenance is far easier than faking the art itself, so now, as well as the usual documentation, a buyer wants to know the results of a scientific analysis. The seller knows he's wise to have had that analysis done. The mindset has changed over the last 20 years.

Is demand for your services growing?

PPB: Yes, especially as the world becomes embroiled in financial turmoil. As people lose faith in currency and investment schemes, they turn to blue-chip art – the secure, high-value art that you know you can buy for a million and sell for a million.

What can you do if you suspect the heirloom hanging on your wall is a lost masterpiece?

NE: The problem is getting heard. Specialists on big names like Constable or Rembrandt are being approached all the time, and sorting the good from the bad is time-consuming for them. People like us know how to present your case to the art world. We can steer your painting through the many pitfalls that exist between the wall at home and the wall in the museum. ■