The big brain teaser

Why did humans evolve such large brains? A surprising new idea gives us insight into the future of humanity, finds **Colin Barras**

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NOBODY doubts that Albert Einstein had a brilliant mind. But the Nobel prizewinner, famous for his theories of special and general relativity, wasn't blessed with a big brain. "It was smaller than average," says Jeremy DeSilva at Dartmouth College in New Hampshire.

This seems surprising. Big brains are a defining feature of human anatomy, and one we are proud of. Other species might be speedy or powerful, but we thrive using the ingenuity that comes with a large brain. Or so we tell ourselves. Einstein's brain hints that the story isn't so simple – and recent fossil discoveries confirm this. Over the past two decades, we have learned that small-brained hominin species survived on Earth long after big-brained ones appeared. Moreover, evidence is growing that they were behaviourally sophisticated. Some, for instance, made complex stone tools that could probably only have been fashioned by individuals with language.

These discoveries turn the question of human brain evolution on its head. "Why would selection favour big brains when small-brained humans can survive on the landscape?" says DeSilva. Neural tissue consumes lots of energy, so big brains must surely have brought benefits to the few species that evolved them. But what?

An answer to this puzzle is beginning to emerge. It looks like brain expansion began as an evolutionary accident and then led to changes that caused this growth to spiral. Surprisingly, the sorts of changes that drove this expansion could also explain a more recent 10 per cent reduction in human brain size. What's more, this suggests our brains may shrink further still – and might even cause humanity's demise.

It is undeniable that hominin brains have grown larger through time. *Sahelanthropus tchadensis*, the oldest known hominin, which wandered northern Africa about 7 million years ago, had a brain volume of around 360 cubic centimetres. The average brain volume of a human today is almost four times that, at 1350 cubic centimetres. Granted, some of this expansion can be explained by the fact that we are larger than most of our hominin ancestors – for example, Lucy, a 3.2-million-year-old hominin, was just 1.1 metres tall. Larger animals tend to have larger brains, says Amélie Beaudet at the University of Cambridge. "But we do need another explanation because, at some point, you see that body mass is not really increasing in ancient humans, but brain size is increasing a lot."

Until a few decades ago, the explanation seemed obvious. Many researchers assumed that the hominin evolutionary tree looked fairly simple, particularly following the evolution around 2 to 3 million years ago of the first species belonging to the genus *Homo* from the more ape-like hominins. The idea was that only one species could occupy the environment at any one time, says Philipp Gunz at the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany. So, *Homo habilis* appeared to thrive until it was replaced by *Homo erectus*, which was superseded by *Homo heidelbergensis*, which itself was supplanted by our species, *Homo sapiens*, in Africa and by the Neanderthals in Eurasia. In each case,

the successor species had a larger brain than its predecessor. Researchers rarely questioned the idea that big-brained humans were smarter and evolutionarily superior to their small-brained ancestors.

Then came some extraordinary discoveries that undermined this assumption. It began 20 years ago when researchers in Indonesia discovered *Homo floresiensis*, a 1.1-metre-tall human with a tiny, 425-cubic-centimetre brain. It survived until astonishingly recently – about 50,000 years ago, according to current estimates. This means that long after our species appeared more than 300,000 years ago, there were small-brained humans on Earth. And *H. floresiensis* wasn't alone. A further discovery around five years ago revealed another small hominin, *Homo luzonensis*, survived in the Philippines until around the same time. Then there is the diminutive *Homo naledi*. Discovered in 2013, it had a brain volume of no more than 550 cubic centimetres – literally pint-sized – but lived in southern Africa alongside our big-brained species until at least 235,000 years ago.

If these discoveries weren't remarkable enough, we now have signs of something even more astonishing: small-brained hominins seem to have been capable of sophisticated behaviour. A striking example of this comes from a site called Gona in Ethiopia. *H. erectus* living there about 1.6 million years ago produced "Acheulean" stone tools. These artefacts, which include teardrop-shaped hand axes, are so difficult to make that experiments suggest it would have required at least rudimentary language to teach and learn the skill. Given that, you might assume the individuals at Gona had large brains. But a 2020 study revealed that at least some of them had brains that were less than half the size of those of people today.

Last year brought a similar revelation. Before hominins made Acheulean tools, they made simpler – but still quite complex – "Oldowan" tools. It has long been thought these were largely the handiwork of *H. habilis*, a species with a brain volume of around 550 cubic centimetres. But at a site called Nyayanga in Kenya, researchers reported finding Oldowan tools up to 3 million years old in association with fossils of *Paranthropus*, a hominin with a brain volume as low as 450 cubic centimetres. Despite its small brain, says Beaudet, *Paranthropus* may have made Oldowan tools.

The most eye-catching claims of all involve *H. naledi*. Researchers have spent a decade analysing a cave in South Africa ›

containing the remains of more than 15 ancient individuals. Last year, the team concluded that the site reveals evidence of remarkably sophisticated behaviour: *H. naledi*, they argued, had used torchlight to carry dead individuals into a deep burial chamber, the walls of which they had decorated with etchings. For most researchers, this is a step too far. "I don't believe *naledi* could bury its dead or make engravings in caves," says Gerhard Weber at the University of Vienna in Austria. Nevertheless, the finds at Gona and Nyayanga suggest that hominins didn't require an overabundance of neural tissue to behave in complex ways. This makes the evolution of large brains a bit of a head-scratcher.

When bigger isn't better

Adding to the puzzle is the fact that big brains carry some clear disadvantages. They are demanding to run: ours consume around 20 per cent of our daily energy intake despite accounting for just 2 per cent of our body mass. Moreover, a baby with a large brain is tricky to deliver and to raise. "Childbirth is difficult," says DeSilva. "And when you're trying to feed this infant with its growing brain, it's an energetically exhausting endeavour."

Nonetheless, hominin brains did evolve to be larger over time. At a conference of the European Society for the Study of Human Evolution in Denmark last year, Thomas Püschel at the University of Oxford and his colleagues showed that this trend was mostly driven by changes within particular species.

"Adding to the puzzle is the fact that big brains carry some clear disadvantages"

Despite its tiny brain, *Homo floresiensis* survived long after our species evolved

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For example, when *H. erectus* first appeared in the fossil record about 2 million years ago, its brain volume was as little as 550 cubic centimetres. By the time the last *H. erectus* were walking Earth, some 108,000 years ago, that volume had doubled.

At the same conference, Weber presented an analysis showing that the rate of brain expansion hasn't been constant, though. Between 7 million and 2 million years ago, average hominin brains increased modestly in size – from about 360 to 450 cubic centimetres. Then they enlarged at a faster rate, ballooning to 1350 cubic centimetres 110,000 years ago. After that, the rate accelerated even further, with brain volume reaching a peak of 1500 cubic centimetres around 50,000 years ago, late in the Stone Age.

One popular hypothesis ties this expansion to changes in diet. "The idea is that when hominins started to eat meat on a more regular basis, we had the energy to develop a bigger brain," says Beaudet. This could explain how brain expansion happened, but not why. In other words, what was the evolutionary advantage of diverting that extra energy to the brain rather than to other parts of the body?

An alternative hypothesis does address the question of why. It states that some hominins began living in bigger social groups and grew larger brains to cope. "If your social environment is more complex, you may need a bigger brain to understand how to live with that complexity," says Beaudet. But there are problems with this idea too. For instance, it implies that brain size should correlate with social group size across primate species – but researchers have failed to find this pattern.

It may be a mistake to pin brain expansion on a single factor. Better diets and larger social groups probably played their part, but it seems likely that there was more going on. One possibility is that brains and behaviour became caught up in a positive feedback loop. Perhaps small-brained hominins developed new tools and basic language skills, thereby boosting their odds of survival. If individuals with slightly larger brains found it easier to master these technologies and behaviours, average brain sizes would have risen as time passed. And as brains grew larger, the population would have found it even easier to improve their tool-making and language skills, leading to further selection for larger brains and making tool production easier still. "Evolution doesn't just invent new brain structures and suddenly you can speak or whatever. It's the other way round," says

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Left: Liang Bua cave in Indonesia where *Homo floresiensis* was first found. Above: Small-brained hominins made complex tools

Christoph Zollikofer at the University of Zurich in Switzerland. "You start speaking and then this creates a new cultural environment under which there are new selective pressures that favour new brain structures."

Accidental advantage

This still doesn't explain why bigger brains would have made tool-making or language easier to master. But Beaudet has an idea. Let's assume a meat-rich diet led to an energy surplus, and some of that energy fuelled brain growth – simply because the extra energy had to go somewhere. But, as brains expanded, they ran into a problem. "At some point, just because the brain is getting bigger, you have no space in the brain case," says Beaudet. The surface of the brain – which was already folded in small-brained humans – would have gained an even more elaborate pattern of folds and furrows as it pressed against the skull. This folding potentially brought neurons from distinct brain regions into closer physical proximity, she says, allowing for greater connectivity between those regions. Purely by chance, some of these connections might have made it easier for humans to talk or make tools. In other words, brain expansion may initially have had no survival advantage, but then serendipitously acquired one – at which point natural selection would have kicked in.

This line of reasoning could even help explain why Einstein's brain, at about 1290 cubic centimetres, was on the small side – and why women are just as smart as men despite having slightly smaller brains.

If evolution were mostly about favouring better-connected brains rather than bigger ones, brain size could vary somewhat without affecting performance. Even so, size clearly matters at least to some extent, which raises questions about a curious event in our recent evolutionary history when brains shrank, going from 1500 cubic centimetres to just 1350 cubic centimetres – the volume we have today. Surprisingly, this shrinking may have had the same underlying cause as brain growth: the development of new technologies and sophisticated behaviours.

In a 2021 study, DeSilva and his colleagues analysed data from hundreds of ancient skulls to work out exactly when this shrinking event occurred. "We were surprised how recent it was: within the 3000-to-5000-year range," he says. This suggests brains downsized at a pivotal moment – just as the first civilisations began to appear and new technologies, including writing, emerged. DeSilva thinks this is no coincidence. He argues that, with these innovations, humans inadvertently relaxed the pressure on evolution to favour individuals with a big brain. For example, writing allowed people to store some of their accrued knowledge externally instead of committing it to memory. Complex societies, meanwhile, meant that the decisions crucial to survival were increasingly taken at a group level. As a consequence, the cognitive demands on individuals lessened and brains could shrink. "It's a really nice narrative," says Püschel – although he cautions that it must be tested more thoroughly.

Nevertheless, researchers do now entertain the idea that changes in society and technology could influence evolution and shape our brains. For some, the big question is whether that is always to our benefit. Weber worries that it might not be. He has suggested that, in the future, it might become even less important for humans to maintain large brains because of the rise of artificial intelligence. "What really worries me is machines that can produce machines," he says. "If an AI can produce the next AI without our intervention, the question is: what is our role then?" In a study published last year, he raised the possibility of a "post-human era" in which AI and other technologies have produced "abiotic beings" and replaced humans.

Others are less concerned. Even if human brains shrank in the past as individuals began to rely more heavily on new technologies, humans clearly continued to flourish. Beaudet thinks we should view AI as the latest in a long line of hominin technologies, stretching back to the pounding stones our ancestors used to process food. Just like those stone tools, AI might simply improve the efficiency with which we carry out certain tasks, affording us more time to dream up even more technologies. "It's been like this since the beginning of the human story and I think it will never stop," she says. "I am a bit worried, but I don't think AI will rule the world." ▮

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