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Can simulating evolution on a computer explain our enormous brains?

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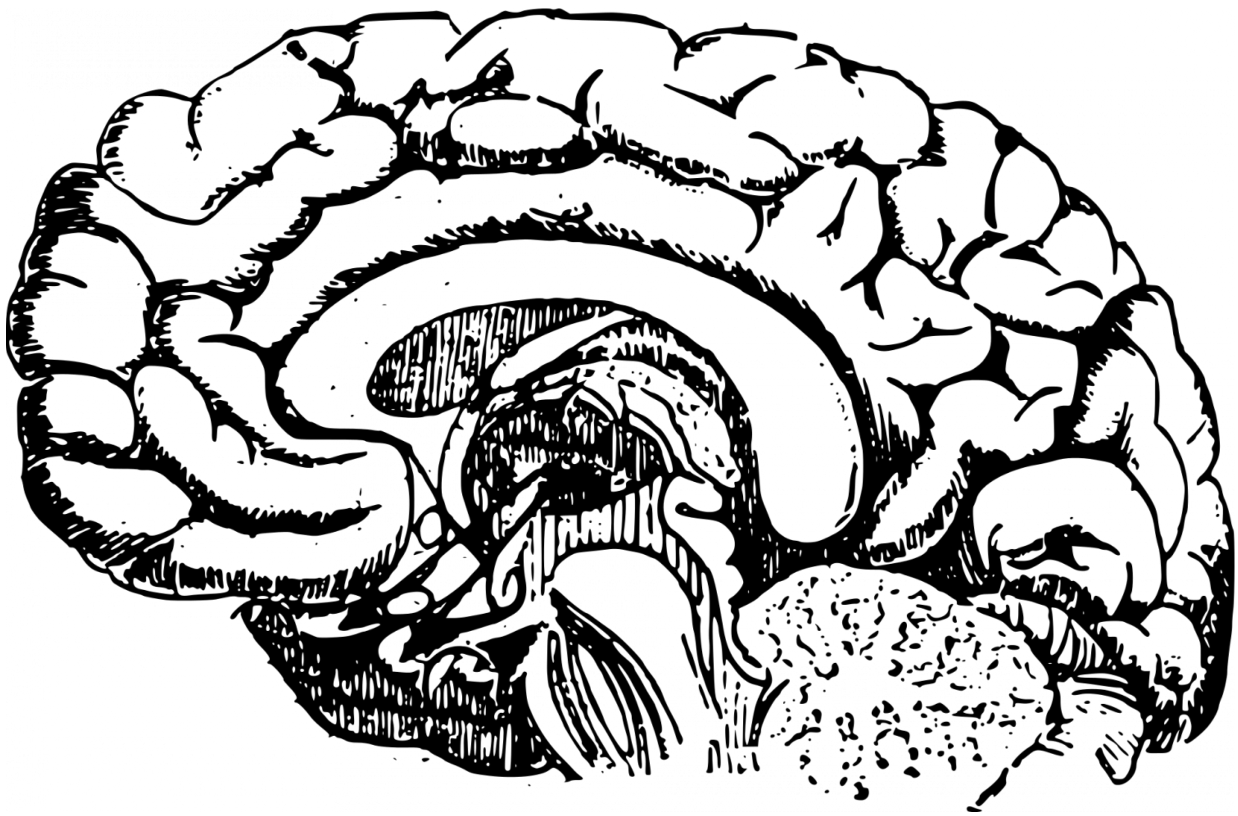

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Compared to the rest of the animal kingdom, the human brain is way out of whack.

Our brains are roughly six times larger than what you would expect for a placental mammal of our stature, scientists say.

And no other animal has a brain as large as ours relative to body size.

So why did humans evolve to have such large brains when other animals did not?

It's a question that evolutionary biologists and anthropologists have been trying to answer for decades.

Our giant brains must have helped our ancestors survive in the African savannah where the first modern humans evolved, but they also came at a metabolic cost.

The human brain represents just 4 percent of our body weight, but it consumes 20 percent of our energy, said Mauricio Gonzalez-Forero, a mathematical evolutionary biologist at the University of St. Andrews in Scotland.

"It's a very expensive organ," he said.

Determining what social and environmental conditions caused our predecessors to develop such disproportionately large, energy-hungry brains has turned out to be a hard problem to solve.

Human brain evolution is not something you can test in the lab. It would take hundreds of years, if not thousands, to reveal how evolutionary pressures shaped the modern human brain. And even if you could do those experiments, they would probably not be ethical.

Instead, previous research has generally focused on the relationship between the brain size of different animals and their ability to find food, learn new skills, and live in groups. Scientists use those correlations to make inferences about why the human brain might have evolved as it did.

But this strategy has limitations, Gonzalez-Forero said. For example, some researchers have found a correlation between large group size and large brain size, he said. But it is not clear what came first—the living in large groups, or the development of a large brain.

In a paper published Wednesday in *Nature*, Gonzalez-Forero set out to approach the question of why our brains got so big in a different way—by attempting to simulate evolution in a computer.

To do this, he started by considering how much energy an adult human female needs to sustain her brain, body tissues and the energetic cost of reproduction.

He also included previously determined data on how the energy requirements of an organism shift depending on its body size and the size of its brain.

For example, a bigger brain might have helped our ancestors find and consume food more efficiently by allowing them to be more adept at tracking and by learning to cook over fire, but that bigger brain also requires more energy. The same holds true for body size.

Next, Gonzalez-Forero identified four challenges that early humans might have faced that could have influenced the evolution of their brain size. These were ecological (me vs. nature), cooperative ecological (us vs. nature), competition between individuals (you vs. me) and competition between groups (us vs. them).

By fiddling with the levels of each of these factors and then running the model through many successive generations, he was able to see which combination of evolutionary pressures were most likely to give rise to the modern human brain size.

According to the results, the size of our brains can best be explained primarily as a response to ecological pressures, but not exclusively. The best match for modern human brain size came when our virtual human ancestors contended with 60 percent ecological challenges, 30 percent cooperative ecological factors, and 10 percent of competition between groups.

The model also suggests that our brains would be even larger if they were molded entirely by the challenge of efficiently extracting energy from the environment, Gonzalez-Forero said. The cooperation among individuals limits how large our brains need to be to survive.

"Cooperation decreases brain size because you can rely on the brain of other individuals and you don't need to invest in such a large and expensive brain," he said.

But why didn't other animals that lived in the same environment as early modern humans develop such large brains as well?

Although Gonzalez-Forero's model doesn't address this question directly, he said it does offer some potential clues. Specifically, the model suggests that human brain size would only develop the way it did if our ancestors were already inclined to acquire new skills throughout their lives.

"Ecological challenges can only lead to brain size of this scale if they are coupled with the ability to continue learning from others," he said. "The paper is suggesting that human brain development is an interaction between these two things—ecological pressures and culture."

Robert Barton, an evolutionary anthropologist at Durham University in England who was not involved in the new work, described the study as extremely ambitious and said he appreciates that the model examines interactions and trade-offs among social and ecological factors.

"This is surely something that has not been considered sufficiently in the past," he said.

However, he added that researchers don't know enough yet to create an accurate model of brain evolution, and that any general model will have extremely limited explanatory powers since it is likely that different forces acted to shape brain size at different times.

"What we have been saying for years is that brain size is not a very useful measure unless you can understand the underlying variation in neural structure," he said.

Robin Dunbar, an evolutionary psychologist at the University of Oxford, offered a more damning critique.

"Computer models are fine, but you get out what you put in—what is known as the GIGO (or garbage in, garbage out) mode of science," he said in an email.

He added that although the work looks impressive, it is misleading in part because the authors misconstrue the ecological problem that animals including hominins, had to cope with, and then confuse the social mechanisms they used to solve these problems.

"(The authors') model of sociality is one of cooperation, when in fact it is one of coordination," Dunbar said. "Cooperation is a consequence of living in groups, not its cause."

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Susanne Shultz, who studies evolutionary biology at the University of Manchester, took issue not with the methodology, but with the conclusions that were gleaned from the work.

"I have a fairly strong opinions about the utility of trying to divide social and ecological challenges into mutually exclusive categories," she said. "After reading the paper several times, I am still convinced that the model and results are more consistent with a 'socio-ecological' brain. Their argument that they find support for an ecological and not social brain just isn't supported by their results."

Gonzalez-Forero expected some pushback to the work, and he admits that although his model is fairly complex and robust, it could always be improved on.

"That's the story of science," he said. "You are never at the end. This is opening up a new way of addressing this question and there is room for a lot of exciting new work to be done."

More information: Inference of ecological and social drivers of human brain-size evolution, *Nature* (2018). 10.1038/s41586-018-0127-x , www.nature.com/articles/s41586-018-0127-x