# 20-million-year-old skull suggests complex brain evolution in monkeys, apes

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An exceptional fossil skull of *Chilecebus carrascoensis*, a 20-million-year-old primate from the Andes mountains of Chile. Credit: © AMNH/N. Wong and M. Ellison

It has long been thought that the brain size of anthropoid primates—a diverse group of modern and extinct monkeys, humans, and their nearest kin—progressively increased over time. New research on one of the

oldest and most complete fossil primate skulls from South America shows instead that the pattern of brain evolution in this group was far more checkered. The study, published today in the journal *Science Advances* and led by researchers from the American Museum of Natural History, the Chinese Academy of Sciences, and the University of California Santa Barbara, suggests that the brain enlarged repeatedly and independently over the course of anthropoid history, and was more complex in some early members of the group than previously recognized.

"Human beings have exceptionally enlarged brains, but we know very little about how far back this key trait started to develop," said lead author Xijun Ni, a research associate at the Museum and a researcher at the Chinese Academy of Sciences. "This is in part because of the scarcity of well-preserved fossil skulls of much more ancient relatives."

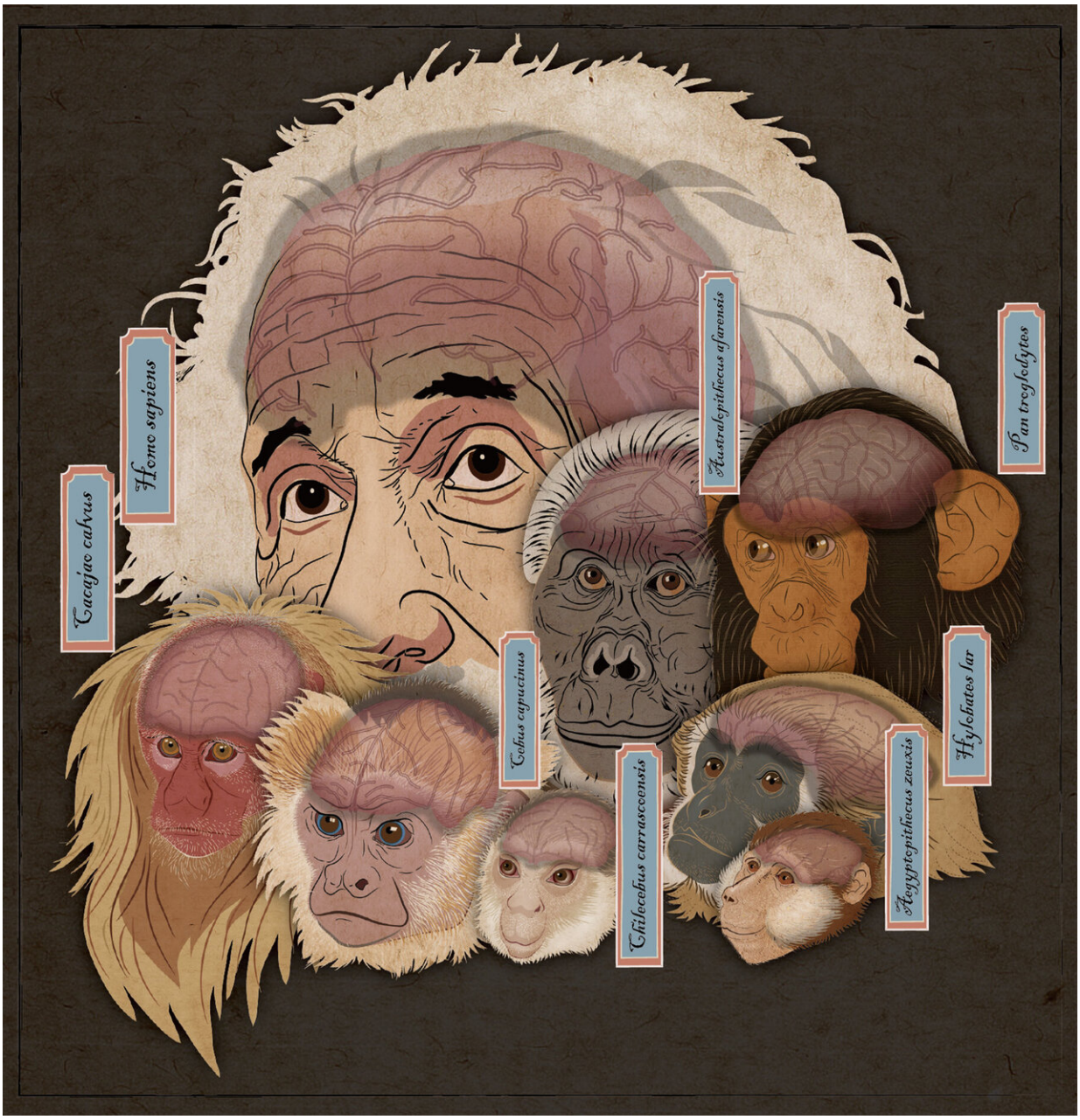
As part of a long-term collaboration with John Flynn, the Museum's Frick Curator of Fossil Mammals, Ni spearheaded a detailed study of an exceptional 20-million-year-old anthropoid fossil discovered high in the Andes mountains of Chile, the skull and only known specimen of *Chilecebus carrascoensis*.

"Through more than three decades of partnership and close collaboration with the National Museum of Chile, we have recovered many remarkable new fossils from unexpected places in the rugged volcanic terrain of the Andes," Flynn said. "*Chilecebus* is one of those rare and truly spectacular fossils, revealing new insights and surprising conclusions every time new analytical methods are applied to studying it."

Previous research by Flynn, Ni, and their colleagues on *Chilecebus* provided a rough idea of the animal's encephalization, or the brain size relative to body size. A high encephalization quotient (EQ) signifies a

large brain for an animal of a given body size. Most primates have high EQs relative to other mammals, although some primates—especially humans and their closest relatives—have even higher EQs than others. The latest study takes this understanding one step further, illustrating the patterns across the broader anthropoid family tree. The resulting "PEQ"—or phylogenetic encephalization quotient, to correct for the effects of close evolutionary relationships—for *Chilecebus* is relatively small, at 0.79. Most living monkeys, by comparison, have PEQs ranging from 0.86 to 3.39, with humans coming in at an extraordinary 13.46 and having expanded brain sizes dramatically even compared to nearest relatives. With this new framework, the researchers confirmed that cerebral enlargement occurred repeatedly and independently in anthropoid evolution, in both New and Old World lineages, with occasional decreases in size.

High-resolution X-ray computed tomography (CT) scanning and 3-D digital reconstruction of the inside of *Chilecebus*' skull gave the research team new insights into the anatomy of its brain. In modern primates, the size of the visual and olfactory centers in the brain are negatively correlated, reflecting a potential evolutionary "trade-off," meaning that visually acute primates typically have weaker senses of smell. Surprisingly, the researchers discovered that a small olfactory bulb in *Chilecebus* was not counterbalanced by an amplified visual system. This finding indicates that in primate evolution the visual and olfactory systems were far less tightly coupled than was widely assumed.




This illustration compares the brain sizes of a variety of primates, including humans (top left) and the fossil *Chilecebus* (bottom middle), based on a new method (phylogenetic encephalization quotient, or PEQ) that takes into account both the body size and the evolutionary relationships of the species. The size of each primate species reflects its PEQ value (large head equals high PEQ, small head equals low PEQ), not its actual brain size or body/head size. For example, a high PEQ (larger heads in this image) signifies a larger than expected brain for an animal of a given body size. Credit: © Xiaocong Guo/Xijun Ni

A high-resolution computed tomography (CT) scan of the Chilecebus carrascoensis fossil skull. Credit: © Xijun Ni and AMNH

Other findings: The size of the opening for the optic nerve suggests that *Chilecebus* was diurnal. Also, the infolding (sulcus) pattern of the brain of *Chilecebus*, although far simpler than in most modern anthropoids, possesses at least seven pairs of sulcal grooves and is surprisingly complex for such an ancient primate.

"During his epic voyage on the Beagle, Charles Darwin explored the mouth of the canyon where *Chilecebus* was discovered 160 years later. Shut out of the higher cordillera by winter snow, Darwin was inspired by 'scenes of the highest interest' his vista presented. This exquisite fossil, found just a few kilometers east of where Darwin stood, would have thrilled him," said co-author André Wyss from the University of California Santa Barbara.

**More information:** X. Ni el al., "Cranial endocast of a stem platyrrhine primate and the ancestral brain conditions in anthropoids," *Science Advances* (2019). advances.sciencemag.org/content/5/8/eaav7913

Provided by American Museum of Natural History

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