Size and shape matter

Evolution can swell or shrink bits of mammals' brains to fit their lifestyles.
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Primates: brain volume could make all the difference.

"It's quite clear that the structure of the brain is ultimately governed by natural selection," says neuroscientist Samuel Wang of Princeton University. His team has worked out what percentage of the total brain volume is taken up by different brain regions in different species. This breakdown, christened 'cerebrotype', could shed light on brain evolution and the relationships between species[1].

Wang and colleagues found that within a particular group, such as tree shrews or Old World monkeys, the relative sizes of different parts of the brain seem to remain fairly constant, despite huge variations in overall brain size. But between groups, there are big differences in brain architecture.

The cerebrotype is a powerful defining feature of an animal's biology, says Wang. "If you handed me a list of numbers [corresponding to the cerebrotype], I could tell you what type of animal it was," he says. He also believes that it can be used to work out the relationships between species.

"It's compelling that a very small primate brain has a similar structure to a very large one," says Jon Kaas, a psychologist at Vanderbilt University.

A change in cerebrotype often accompanies -- perhaps even defines -- the evolution of new groups. For example, the evolutionary passage from primitive lemurs through to more recent monkeys, apes and humans is mirrored by a relative enlargement of the neocortex.

The neocortex, the most recently evolved brain region, does what we regard as the clever stuff: learning, language and making sense of the world. It takes up about 80% of the human brain but less than 60% of a New World monkey's brain. The researchers believe that this could reflect an adaptation for living in larger groups with more complex social interactions.

Wang and colleagues also uncovered some similarities between distantly related species. Bats and dolphins, which navigate using echolocation, both have a large cerebellum -- a structure that is thought to coordinate sensory input with muscular responses. So too do fish that send out pulses of electricity and detect the reflections.

Brain teaser

But it may take more than a new technique to reconcile researchers long divided over how much a species' evolutionary history, developmental programming and ecology contribute to its brain makeup, and over which brain measurements best address these questions.

Robert Barton, an anthropologist at the University of Durham, UK, who has used a different technique to compare brain areas[2], takes issue with many of Wang and colleagues' methods and conclusions.

For example, Wang's team found that the cerebellum occupies a more-or-less constant proportion of brain volume across many species, and take this as evidence that its function is independent of what's going on in the rest of the brain. "I would dispute that cerebellum size is constant across species," says Barton.

"If one structure [the neocortex] has expanded massively, then other structures that haven't should be a smaller proportion." The fact that this isn't the case for the cerebellum, says Barton, shows that it too has grown in primates with a big neocortex. Barton believes that the use of proportions as a measure of brain architecture cannot adequately describe the way that different brain regions vary with respect to one another.

Kaas, however, thinks that the different techniques are complementary, rather than contradictory. "All the studies are useful," he says. "The conclusions of one don't invalidate those of another."

Volume of evidence

Charles Stevens, of the Salk Institute in La Jolla, California, takes a still different approach, arguing that the number of cells can tell you more than the volumes of different regions. "Our brain is no different from a mouse's," he says, "but we have a lot more of it."

Stevens has counted the cells in two regions of the cortex: the lateral geniculate nucleus (LGN), one of the first destinations for nerve signals from the retina, and the primary visual cortex, the next port of call for LGN messages[3].

He found that, in a range of primate species, the number of cells in the primary visual cortex is proportional to the number of cells in the LGN raised to the power of 1.5. So a human uses four times as many neurons to process the input from each LGN neuron as a tarsier, a small Asian primate.

Stevens suggests that bigger animals with bigger eyes need proportionally more cortical cells to process the information they receive without sacrificing resolution.