Are Whales the World's Biggest Brainiacs?

(ANIMAL INTELLIGENCE) Too bad, Ahab. Moby Dick's brain is more than five times larger than a human brain. But is size all that matters? From Scientific American, here's a brainy article on how whales compare to people in intelligence. – Global Animal

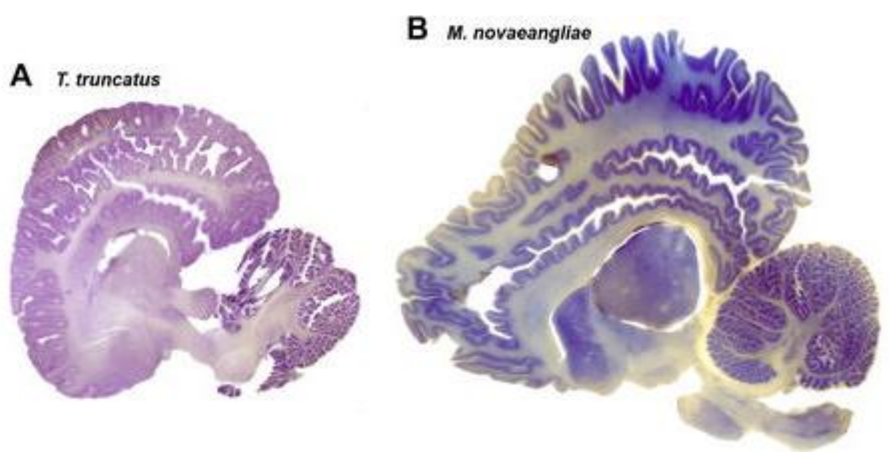
…We humans pride ourselves on our big brains. We never seem to tire of bragging about how our supreme intelligence empowers us to lord over all other animals on the planet. Yet the biological facts don't quite square with Homo sapiens' arrogance. The fact is, people do not have the largest brains on the planet, either in absolute size or in proportion to body size. Whales, not people, have the biggest brains of any animal on earth. Just how smart are whales? Why do they have such big brains? Bigger is not always better; maybe the inflated whale brain is not very sophisticated on a cellular level. We're closer to answering such questions now, for a couple of recent papers address them squarely. What they find is helping separate fact from fiction.

Size matters, but it's not everything: The largest brain on earth belongs to the sperm whale, the same species as the main character in Melville's yarn. The adult sperm whale brain is 8,000 cubic centimeters. Our brain is about 1300 cubic centimeters. This is equivalent to the difference in engine displacement (the space in the cylinders) of a 1960s VW beetle compared with two and a half Formula One race cars. Porpoises and elephants, fellow mammals known for their extraordinary mental abilities, also have bigger brains than we humans. But that's not fair. Those animals are humongous. You need to take into account brain-to-body size. When this is done, the winner is .. well, the tree shrew, followed by humans and then porpoises. Okay, tree shrews have the biggest brain-to-body ratio because they have such tiny bodies. No one thinks tree shrews are intellectual giants. All this calculation does is bring us back to where we started — humans and whales have very big brains. It is going to take more than a meat scale to distinguish any difference in the intellectual power between these brains.

A look backwards: In her new paper in PLOS Biology, Dr. Lori Marino of Emory University takes a look at the paleontological evidence. Humans are widely considered the most highly evolved species. Never mind that our DNA differs from the chimp's by only 2 percent; just look at how our head swelled, in only 3 million years, from the puny 380-cubic-centimeter brain of "Lucy", *Australopithecus afarensis*, to the modern 1300-cubic-centimeter cranial capacity of *Homo sapiens*. But consider the whale, whose closest living ancestor is the hippopotamus. The hippo's brain-to-body ratio is unimpressive for a mammal, 1.27, (similar to that of many sharks); nevertheless this modest brain is adequate for the cerebral challenges of a mud-wallowing life-style. Enormous evolutionary changes were required to transform a bog-dwelling tetrapod into a streamlined ocean-going Leviathan. “Adaptation of cetaceans to a fully aquatic lifestyle represents one of the most dramatic transformations in mammalian evolutionary history,” Dr. Marino concludes.

Dramatic transformations in physiology and body structure were required to realize the hippo’s dream of roaming supreme in the ocean. Jettisoning legs, transforming forelimbs into flippers, moving the nostril to the top of the head, developing sonar, underwater vision and hearing — these evolutionary advances raise the question of whether the process of becoming fully aquatic might have been related to the very large brain of whales. By carefully examining the fossil record she found that the sudden boost in brain size in ancestors to modern whales came 10 million years after their ancient ancestors became fully aquatic. This sinks the idea that transformation to an aquatic lifestyle inflated the whale brain. It wasn’t the new environment alone that spurred the big brain. A closer look at the neuroanatomy of the human and whale brain reveals that the whale cerebral cortex is much more convoluted than the human cortex. The area of the human neocortical surface is 2,275 cm2 (about the size of a dinner napkin), but the common dolphin neocortical area is 3,745 cm2 (bigger than an unfolded news paper).

The sperm whale? No one has measured it, but it’s vastly larger than a newspaper. Applying the fudge factor of dividing cortical surface area by brain weight does not help: humans have a “gyrification index” of 1.75, but dolphins top out at 2.7, and the killer whale, a brilliant predator that hunts in packs, exceeds this. Marino concludes that evolution to an aquatic lifestyle cannot account for the large size of the whale brain. From the neuroanatomical evidence she concludes that the large whale brain supports a complex intelligence that is driven by the socially complex and highly communicative lifestyle of these predators. In support of this conclusion, baleen whales, which filter plankton and krill for food, do not have brains nearly as large, compared to body size, as toothed whales that hunt their food.



From macro to micro: Meanwhile, in another paper, “Total Neocortical Cell Number in the Mysticete Brain,” Nina Eriksen and Bente Pakkenberg of the University of Copenhagen take the investigation of whale intelligence to a microscopic level and ask a simple question: If the whale brain is so much bigger than the human brain, does this mean it has more neurons? Logically, brain function and intelligence must relate to the number of neurons. Intelligence resides in the neocortex (the thin, convuluted “rind” of the brain) rather than in other, underlying areas devoted to controlling vital housekeeping functions for the body, so Eriksen and Pakkenberg focused their investigation there. The frontal lobes of the dolphin brain are comparatively smaller than in other mammals, but the researchers found that the neocortex of the Minke whale was surprisingly thick. The whale neocortex is thicker than that of other mammals and roughly equal to that of humans (2.63 mm). However, the layered structure of the whale neocortex is known to be simpler than that of humans and most other mammals. In particular, whales lack cortical layer IV, and thus have five neocortical layers to humankind’s six. This means that the wiring of connections into and out of the neocortex is much different in whales than in other mammals.

The researchers’ cellular census revealed that the total number of neocortical neurons in the Minke whale was 12.8 billion. This is 13 times that of the rhesus monkey and 500 times more than rats, but only 2/3 that of the human neocortex.

What can account for the fact that whales have bigger brains — and similarly thick neocortexes — but fewer neurons? Eriksen and Pakkenberg found that there were 98.2 billion non-neuronal cells, called glia, in the Minke whale neocortex. This is the highest number of glial cells in neocortex seen in any mammal studied to date. The ratio of neocortical glial cells to neocortical neurons is 7.7 to 1 in Minke whales and only 1.4 to 1 in humans. This finding may indicate a tendency for larger glia/neuron ratios as brain mass increases to support the growing neurons. But when one considers other recent research revealing that glia play an important role in information processing (see "The Other Half of the Brain," from Sci. Am. April 2004), one is left to wonder. Is the whale brain intellectually weaker than the human brain, or just different? They have fewer neurons but more glia, and in traditional views of the glia, the neurons count for much more. But if glia process information too, does the different ratio in Minke whales mean they think not more weakly but just much differently?

We're now wondering, essentially, what goes on in a whale's head — and why, if it's supposedly so smart, it doesn't have great works to show for it. Many have argued that humans dominate the planet because we have manipulative hands that enable us to make tools, be they harpoons or missiles. What would be the cetacean equivalent? One wonders how different life on earth might have been if humans, big brains and all, had flippers instead of hands — and, perhaps, a lot more glia.

–R. Douglas Fields, who researches glia in his day job, frequently writes on neuroscience for Scientific American and Scientific American Mind.

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