NEUROANATOMY

Does Brain Size Matter?

A recent discovery proves embarrassing to any notion of humanity's innate superiority

ALAMY (*illustration*); SEAN McCABE (*Koch*)

While "size does not matter" is a universally preached dictum among the politically correct, everyday experience tells us that this can't be the whole story—under many conditions, it clearly does. Consider the size of Woody Allen's second favorite organ, the brain.

Adjectives such as "highbrow" and "lowbrow" have their origin in the belief, much expounded by 19th-century phrenologists, of a close correspondence between a high forehead—that is, a big brain—and intelligence. Is this true? Does a bigger brain make you necessarily smarter or wiser? And is there any simple connection between the size of a nervous system, however measured, and the mental powers of the owner of this nervous system? While the answer to the former question is a conditional "yes, somewhat," the lack of any accepted answer to the second one reveals our ignorance of how intelligent behavior comes about.

Bigger Is Slightly Better

The human brain continues to grow until it reaches its peak size in the third to fourth decade of life. An MRI study of 46 adults of mainly European descent found that the average male had a brain volume of 1,274 cubic centimeters (cm^3) and that the average female brain measured 1,131 cm^3. Given that a quart of milk equals 946 cm^3, you could pour a bit more than that into a skull without any of it spilling out. Of course, there is considerable variability in brain volume, ranging from 1,053 to 1,499 cm^3 in men and between 975 and 1,398 cm^3 in women. As the density of brain matter is just a little bit above that of water plus some salts, the average male brain weighs about 1,325 grams, close to the proverbial three pounds often cited in U.S. texts.

Removing brains after their owners died revealed that Russian novelist Ivan Turgenev's brain broke the two-kilogram barrier, coming in at 2,021 grams, whereas writer Anatole France's brain could barely bring half of that weight on the scale at 1,017 grams. (Note that postmortem measures are not directly comparable to data obtained from living brains.) In other words, gross brain size varies considerably across healthy adults.

What about smarts? We all know from our day-to-day interactions that some people just don't get it and take a long time to understand a new concept; others have great mental powers, although it is impolite to dwell on such differences too much. Think of Bertie Wooster, an idle but clueless rich man, and Jeeves, his genius valet, in a series of novels by P. G. Wodehouse and their successful British adaptation to the small screen.

Individuals differ in their ability to understand new ideas, to adapt to new environments, to learn from experience,

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to think abstractly, to plan and to reason. Psychologists have sought to capture these differences in mental capacities via a number of closely related concepts such as general intelligence (*g*, or general cognitive ability) and fluid and crystalline intelligence. These differences in people's ability to figure things out on the spot and to retain and apply insights that they learned in the past to current circumstances are assessed by psychometric intelligence tests. These observations are reliable, in that different tests strongly correlate with one another. They are also stable across decades. That is, measures such as the intelligence quotient (IQ) can be repeatedly and reliably obtained from the same subjects nearly 70 years later.

Differences in general intelligence, assessed in this way, correlate with success in life, with social mobility and job performance, with health and with life span. In a study of one million Swedish men, an increase in IQ by one standard deviation, a measure of variability, was associated with an amazing 32 percent reduction in mortality. Smarter people do better in life. Whereas a high IQ may not predispose people to be happy or to understand the finer points of dating, the highly intelligent are more likely to be found among hedge-fund managers than among supermarket checkout clerks.

What about any numerical relation between brain size and intelligence? Such correlations were difficult to establish in the past when only pathologists had access to skulls and their content. With structural MRI imaging of brain anatomy, such measurements are now routine. In healthy volunteers, total brain volume weakly correlates with intelligence, with a correlation value between 0.3 and 0.4 out of a possible 1.0. In other words, brain size accounts for between 9 and 16 percent of the overall variability in general intelligence. Functional scans, used to look for brain areas linked to particular mental activities, reveal that the parietal, temporal and frontal regions of the cortex, along with the thickness of these regions, correlate with intelligence but, again, only modestly so. Thus, on average, a bigger brain is associated with somewhat higher intelligence. Whether a big brain causes high intelligence or, more likely, whether both are caused by other factors remains unknown.

Recent experiments take into account the particular connections among neurons in certain regions of an individual's brain, much like a neural fingerprint. They do better at predicting fluid intelligence (the capacity to solve problems in novel situations, to find and match patterns, to reason independently of specific domains of knowledge), explaining about 25 percent of the variance in this measure from one person to the next.

Our ignorance when it comes to how intelligence arises from the brain is accentuated by several further observations. As alluded to earlier, the adult male's brain is 150 grams heavier than the female's organ. In the neocortex, the part of the forebrain responsible for perception, memory, language and reasoning, this disparity translates to 23 billion neurons for men versus 19 billion for women. As no difference exists in the average IQ between the two genders, why is there a difference in the basic number of switching elements?

It is also well established that the cranial capacity of *Homo neanderthalensis,* the proverbial caveman, was 150 to 200 cm^3 bigger than that of modern humans. Yet despite their larger brain, Neandertals became extinct between 35,000 and 40,000 years ago, when *Homo sapiens* shared their European environment. What's the point of having big brains if your small-brained cousins outcompete you?

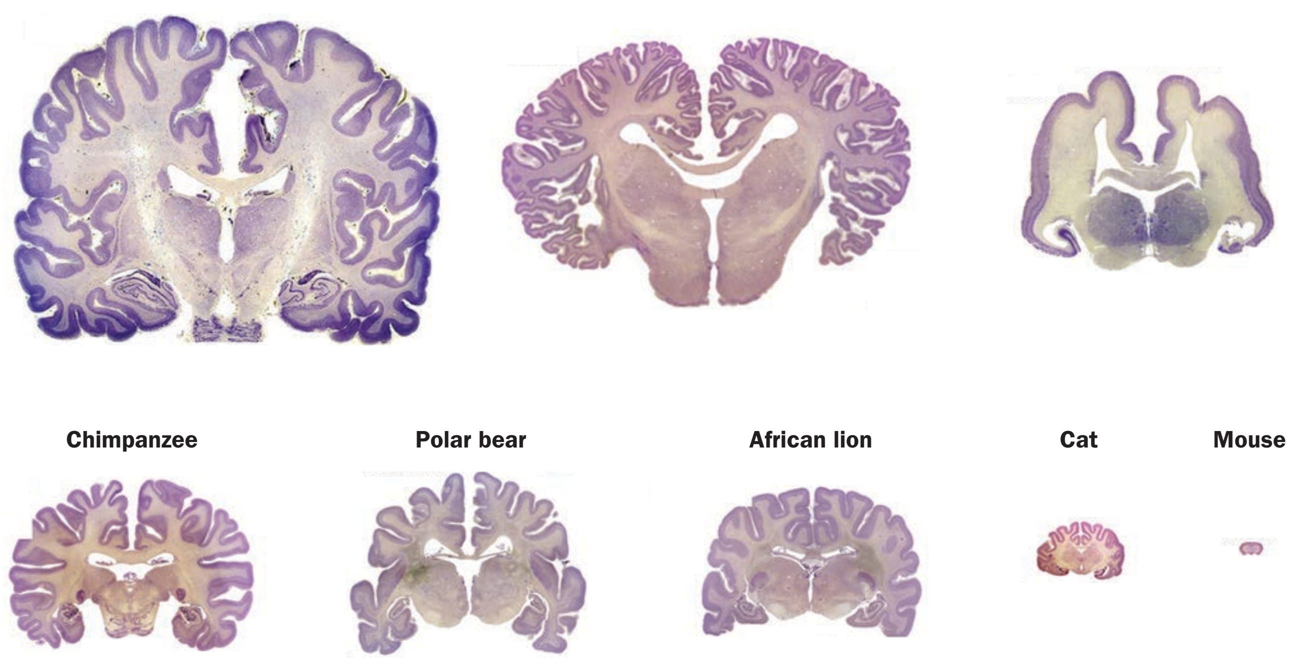
RUSSIAN NOVELIST IVAN TURGENEV'S BRAIN BROKE THE TWO-KILOGRAM BARRIER. WRITER ANATOLE FRANCE'S **BRAIN WAS BARELY HALF THAT.**

Brain Size across Species

Our lack of understanding of the multiplicity of causes that contribute to intelligence becomes even more apparent when looking outside the genus *Homo*. Many animals are capable of sophisticated behaviors, including sensory discrimination, learning, decision making, planning and highly adaptive social behaviors.

Consider honeybees. They can recognize faces, communicate the location and quality of food sources to their sisters via the waggle dance, and navigate complex mazes with the help of cues they store in short-term memory. And a scent blown into a hive can trigger a return to the site where the bees previously encountered this odor, a type of associative memory that guides them back and that was made famous by Marcel Proust in his *Remembrance of Things Past* (*À la Recherche du Temps Perdu*). The insect does all of this with fewer than one million neurons that weigh around one thousandth of a gram, less than one millionth the size of the human brain. Yet are we really a million times smarter? Certainly not if I look at how well we govern ourselves.

The prevailing rule of thumb holds that the bigger the animal, the bigger its brain. After all, a bigger creature has more skin that has to be innervated and more muscles to control and requires a larger brain to service its body. Thus, it makes sense to control for overall size when studying brain magnitude. By this measure, humans have a relative brain-



From man to mouse: Frontal slices of eight mammalian brains reveal the immense variety in the size of the organ and the patterning of surface convolutions that have evolved over the course of tens of millions of years. The smoothness of the manatee's brain surface contrasts with the cauliflowerlike branching in the bottlenose dolphin. Structural differences extend down to the microscopic scale. Scientists are still laboring to understand what the varying anatomy means for animal intelligence.

SOURCE: "THE EVOLUTION OF THE BRAIN, THE HUMAN NATURE OF CORTICAL CIRCUITS, AND INTELLECTUAL CREATIVITY," BY JAVIER DEFELIPE, IN *FRONTIERS IN NEUROANATOMY*, VOL. 5, ARTICLE NO. 29. PUBLISHED ONLINE MAY 16, 2011

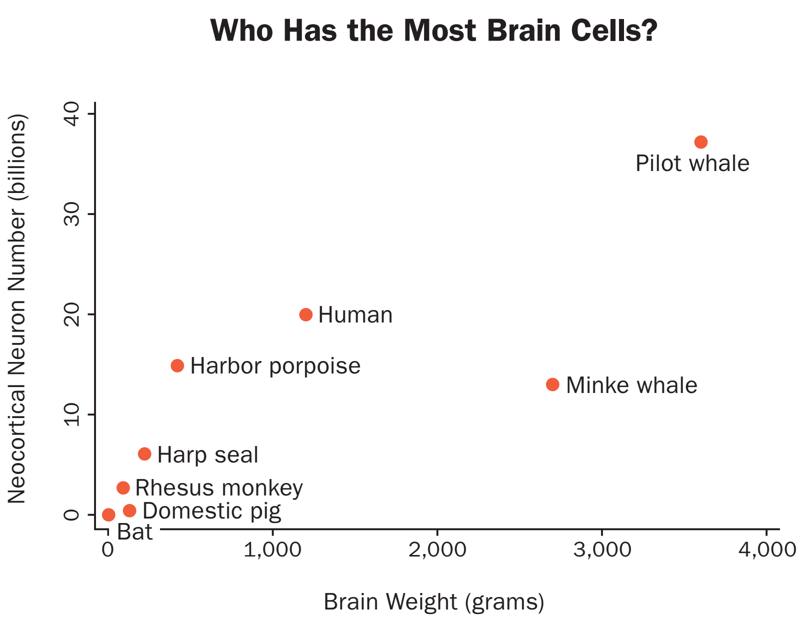
to-body mass of about 2 percent. What about the big mammals—elephants, dolphins and whales? Their brains far outweigh those of puny humans, up to 10 kilograms for some whales. Given their body mass, ranging from 7,000 kg (for male African elephants) up to 180,000 kg (for the blue whale), their brain-to-body ratio is under a tenth of a percent. Our brains are far bigger relative to our size than those of these creatures. Smugness is not in store, though. We are outclassed by shrews, molelike mammals, whose brain takes up about 10 percent of their entire body mass. Even some birds beat us on this measure. Hmm.

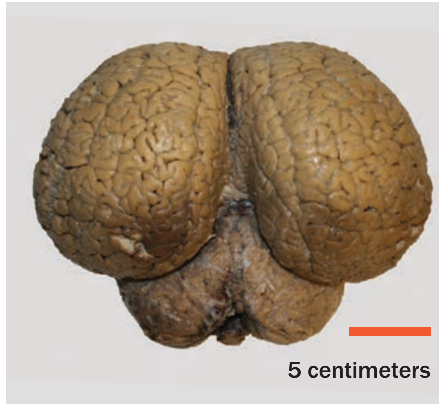
One small consolation is an invention of neuroanatomists called the encephalization quotient (EQ). It is the ratio of the mass of the brain of the species under investigation relative to a standard brain belonging to the same taxonomic group. Thus, if we consider all mammals and compare them against the cat as a reference animal (which therefore has an EQ of 1), people come out on top with an EQ of 7.5. Stated differently, the human brain is 7.5 times bigger than the brain of a typical mammal weighing as much as we do. Apes and monkeys come in at or below five, as do dolphins and other cetaceans. We finally made it to the top, validating our ineradicable belief in humanity's exceptionalism.

Yet it is not quite clear what all this means in terms of the cellular constituents of brains. Neuroscientists always assumed that humans have more nerve cells where it counts, in the neocortex, than any other species on the planet, no matter the size of their brain.

A 2014 study of 10 long-finned pilot whales from the Faeroe Islands plays havoc with this hypothesis. Caught as part of a local hunt in the cold waters of the North Atlantic, between Scotland

A STUDY OF PILOT WHALES PLAYS HAVOC WITH THE NOTION THAT HUMANS HAVE MORE NERVE CELLS WHERE IT COUNTS THAN **ANY OTHER SPECIES ON THE PLANET.**





Bested by a dolphin: The long-finned pilot whale appears to have more neurons in the neocortex—an area devoted to higher mental processes—than any other mammal, about twice the number found in the human cortex. This type of dolphin and its massive brain are shown in the two images at the right.

SOURCE: "QUANTITATIVE RELATIONSHIPS IN DELPHINID NEOCORTEX," BY HEIDI S. MORTENSEN ET AL., IN *FRONTIERS IN NEUROANATOMY*, VOL. 8, ARTICLE NO. 132. PUBLISHED ONLINE NOVEMBER 26, 2014 (*chart*); HEIDI S. MORTENSEN (*brain*); ÓLAVUR FREDERIKSEN (*pilot whale*)

and Iceland, these graceful mammals—also known as blackfish—are actually dolphins. The number of nerve cells making up their highly convolved neocortex was estimated in a few sample slices and then extrapolated to the entire structure. The total came to an astonishing 37.2 billion neurons. Astonishing because this implies that the long-finned pilot whale has about twice as many neocortical neurons as humans do!

If what matters for cognitive performance is the number of neocortical neurons, these dolphins should be smarter than all other extant creatures, including us. Whereas the highly playful and social dolphins exhibit a variety of skills, including the ability to recognize themselves in a mirror, they do not possess language or any readily discernible powers of abstraction that stand out from those of other nonhuman animals. So what gives? Is the complexity of the nerve cells themselves substantially less than cells found in people, or is the way these neurons communicate or learn less sophisticated? We don't know.

People forever ask for *the* single thing that distinguishes humans from all other animals, on the supposition that this one magical property would explain our evolutionary success—the reason we can build vast cities, put people on the moon, write *Anna Karenina* and compose *Eroica*. For a while it was assumed that the secret ingredient in the human brain could be a particular type of neuron, so-called spindle or von Economo neurons, after Baron Constantin von Economo (1876–1931).

But we now know that not only great apes but also whales, dolphins and elephants have these neurons in their frontal cortex. So it's not brain size, relative brain size or absolute number of neurons that distinguishes us. Perhaps our wiring has become more streamlined, our metabolism more efficient, our synapses more sophisticated.

As Charles Darwin surmised, it is very likely a combination of a great many different factors that jointly, over the gradual course of evolution, made us distinct from other species. We are unique, but so is every other species, each in its own way. **M**

MORE TO EXPLORE

- **The Evolution of the Brain, the Human Nature of Cortical Circuits, and Intellectual Creativity.** Javier DeFelipe in *Frontiers in Neuroanatomy,* Vol. 5, Article No. 29. Published online May 16, 2011.
- **Quantitative Relationships in Delphinid Neocortex.** Heidi S. Mortensen et al. in *Frontiers in Neuroanatomy,* Vol. 8, Article No. 132. Published online November 26, 2014.