Researchers use expanding gels to mimic creation of folds in mammalian brain

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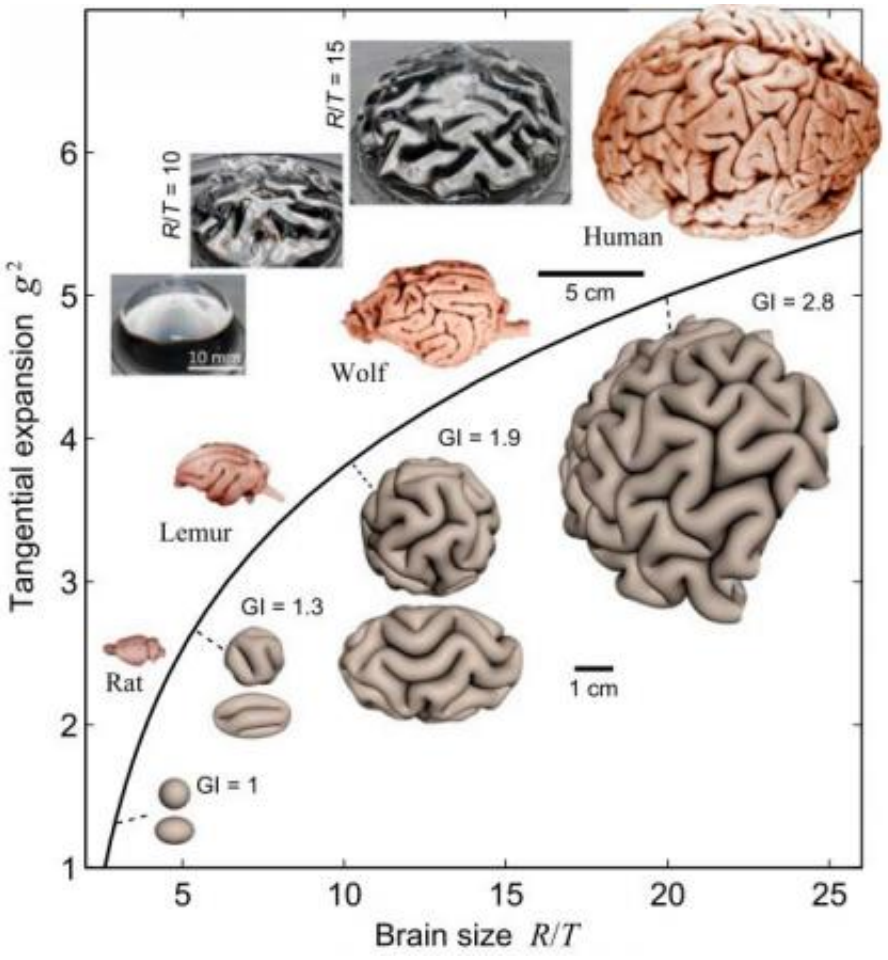

Known empirical scaling laws for gray-matter volume and thickness are mapped on a g2 vs. R/T diagram. Corresponding simulations for spherical brain configurations, with images shown at a few points, show that the surface remains smooth for the smallest brains, but becomes increasingly folded as the brain size increases. Credit: (c) Tuomas Tallinen, *PNAS*, doi: 10.1073/pnas.1406015111

(Medical Xpress)—A team of researchers with members from facilities in Finland, the U.S., and the U.K. has found a way to mimic the process that leads to folds in mammalian brains. In their paper published in *Proceedings of the National Academy of Sciences*, the team describes how they developed computer models to explain the development of folds in the cerebral cortex and then used what they'd learned to mimic the process using expanding gels.

The human brain is instantly recognizable, though most people have never actually seen one in real life—models, pictures and other depictions have stamped the indelible impression of a jellied structure with deep folds, in our own minds. But, why are there folds (made up of ridges and valleys known as gyri and sulci) in the first place? The most obvious answer is that it allows for more surface area. Also, how exactly does the outer part of the brain (the grey matter, or cerebral cortex) grow the way it does with all those folds? Some have suggested it happens because parts of the cortex simply grow more than others, while others have thought it might be due to groups of neuron bundles in white matter pulling the valleys down. In this new effort, the researchers take a more practical approach—trying to mimic the process in a lab.

The team began by assuming that both types of gel-like matter were nearly equal in stiffness—using that idea as a basis they developed a math-based computer simulation that showed gels growing in ways similar to the way mammal brains grow. In so doing they were able to mimic the way the brain develops in a wide variety of mammals (the larger the brain, the more folds). Encouraged the team then created a real world example of their results using two types of gels that can be caused to expand due to chemical reaction, but don't mix with one another—instead they cling. One gel represented the inner white matter, the other the outer grey matter. When the inner gel expanded slower than the outer gel, folds formed on the outer gel, due to buckling, mimicking the familiar mammalian brain, including human.

The team's work suggests that the cortex develops folds the way it does because of the equal stiffness of the matter and because the two types of matter cling tightly to one another as they grow, resulting in the buckling of the outer layer.

More information: Gyrification from constrained cortical expansion, Tuomas Tallinen, *PNAS*, DOI: 10.1073/pnas.1406015111

Abstract

The exterior of the mammalian brain—the cerebral cortex—has a conserved layered structure whose thickness varies little across species. However, selection pressures over evolutionary time scales have led to cortices that have a large surface area to volume ratio in some organisms, with the result that the brain is strongly convoluted into sulci and gyri. Here we show that the gyrification can arise as a nonlinear consequence of a simple mechanical instability driven by tangential expansion of the gray matter constrained by the white matter. A physical mimic of the process using a layered swelling gel captures the essence of the mechanism, and numerical simulations of the brain treated as a soft solid lead to the formation of cusped sulci and smooth gyri similar to those in the brain. The resulting gyrification patterns are a function of relative cortical expansion and relative thickness (compared with brain size), and are consistent with observations of a wide range of brains, ranging from smooth to highly convoluted. Furthermore, this dependence on two simple geometric parameters that characterize the brain also allows us to qualitatively explain how variations in these parameters lead to anatomical anomalies in such situations as polymicrogyria, pachygyria, and lissencephalia.