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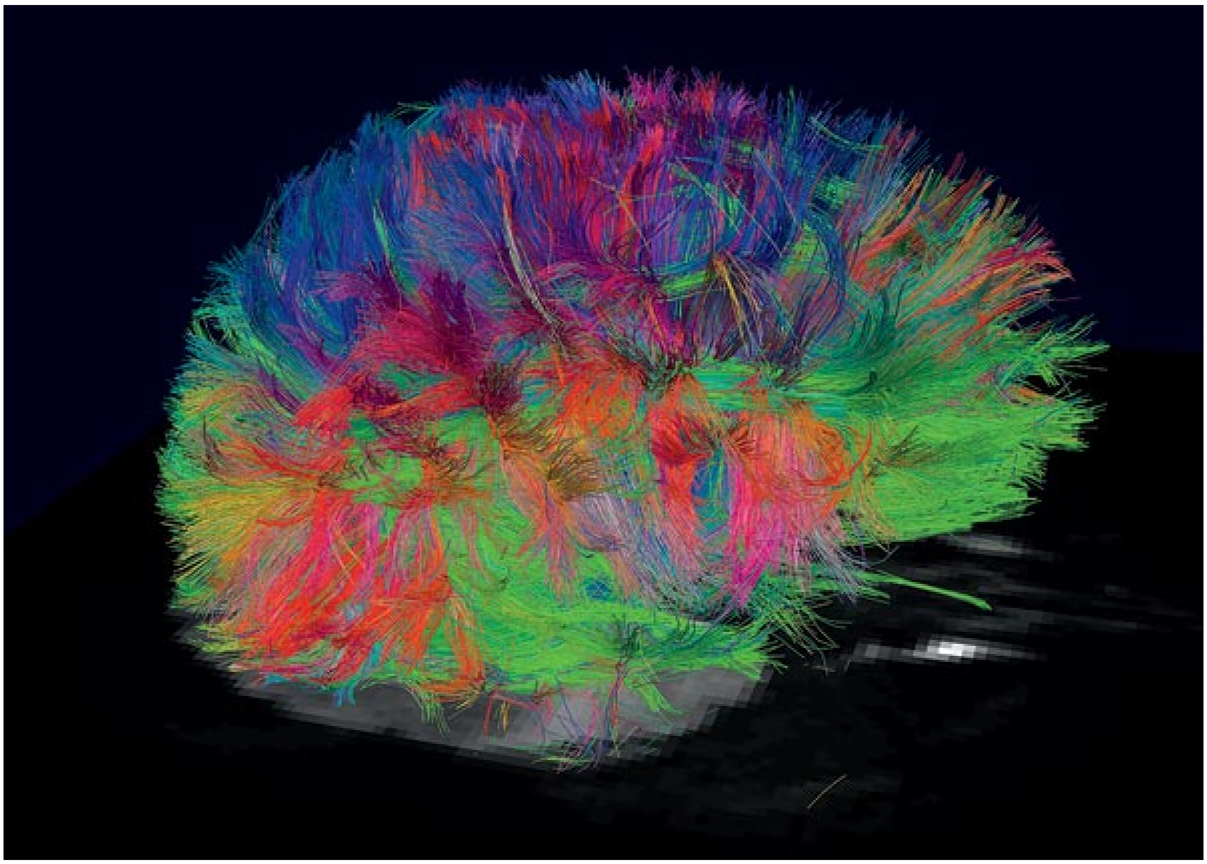
The Brain Unveiled

A new imaging method offers a spectacular view of neural structures.

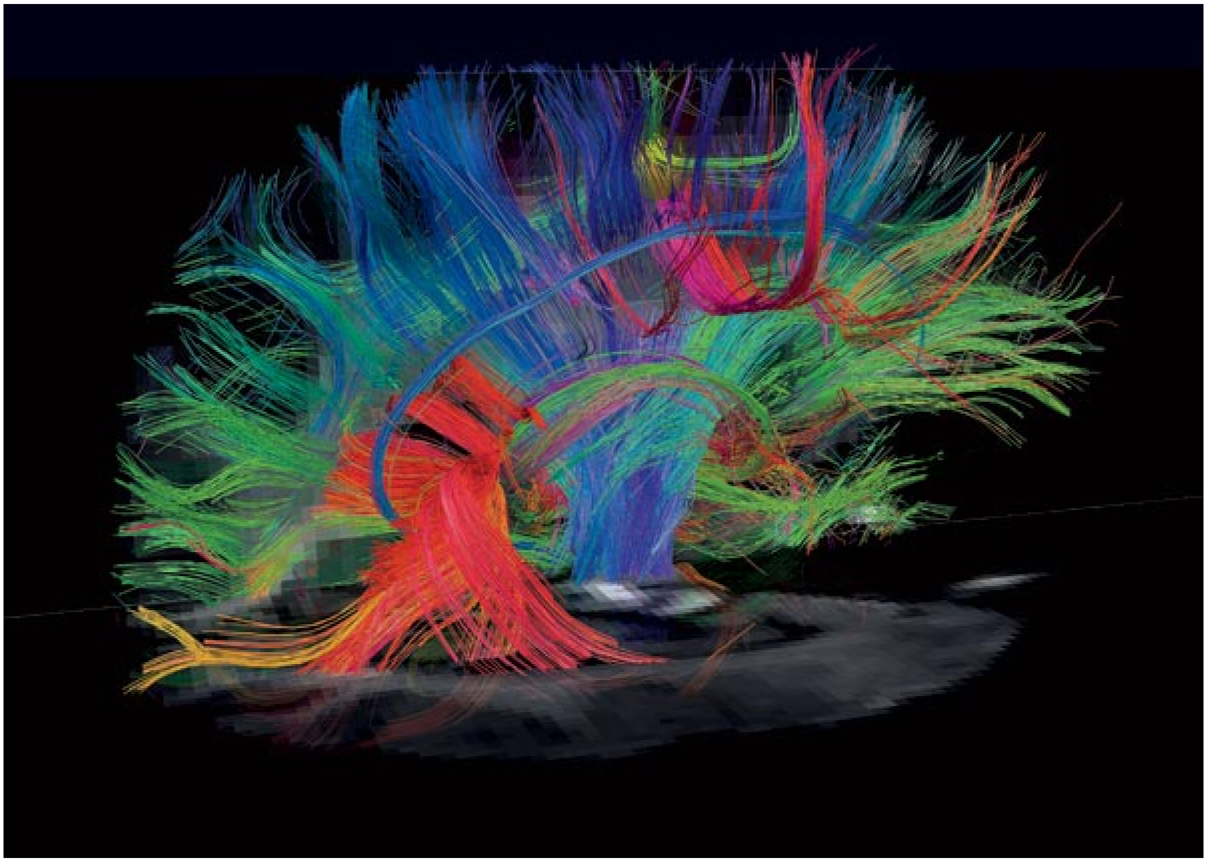
By Emily Singer

A new imaging method that offers an unprecedented view of complex neural structures could help explain the workings of the brain and shed light on neurological diseases.



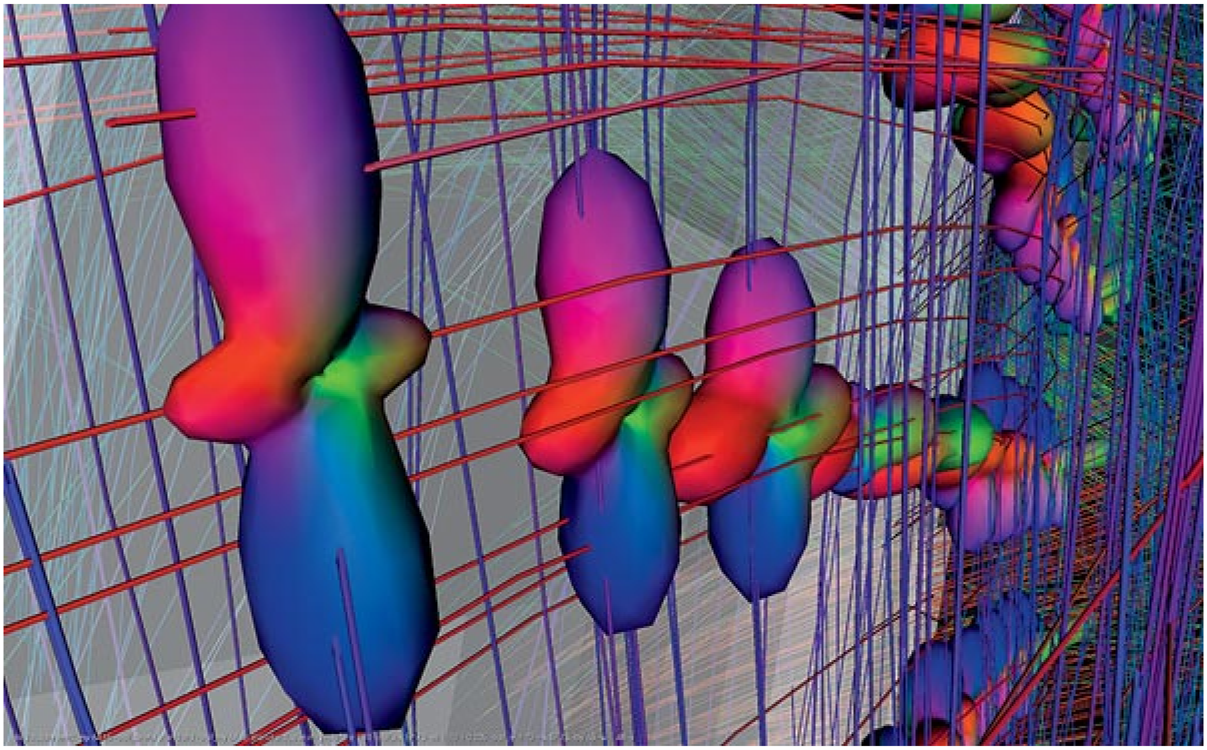
Brain Connections

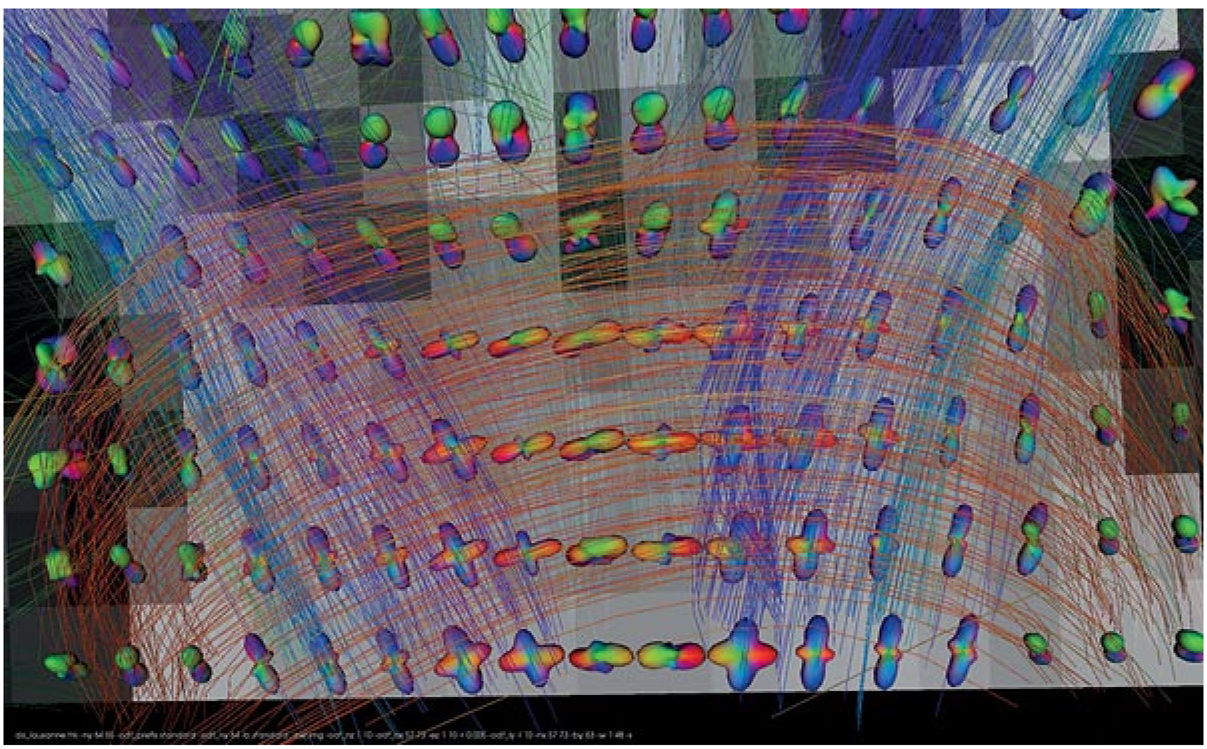
Diffusion spectrum imaging, developed by neuroscientist Van Wedeen at Massachusetts General Hospital, analyzes magnetic resonance imaging (MRI) data in new ways, letting scientists map the nerve fibers that carry information between cells. These images, generated from a living human brain, show a reconstruction of the entire brain (above) and a subset of fibers (below). The red fibers in the middle and lower left of both images are part of the corpus callosum, which connects the two halves of the brain.



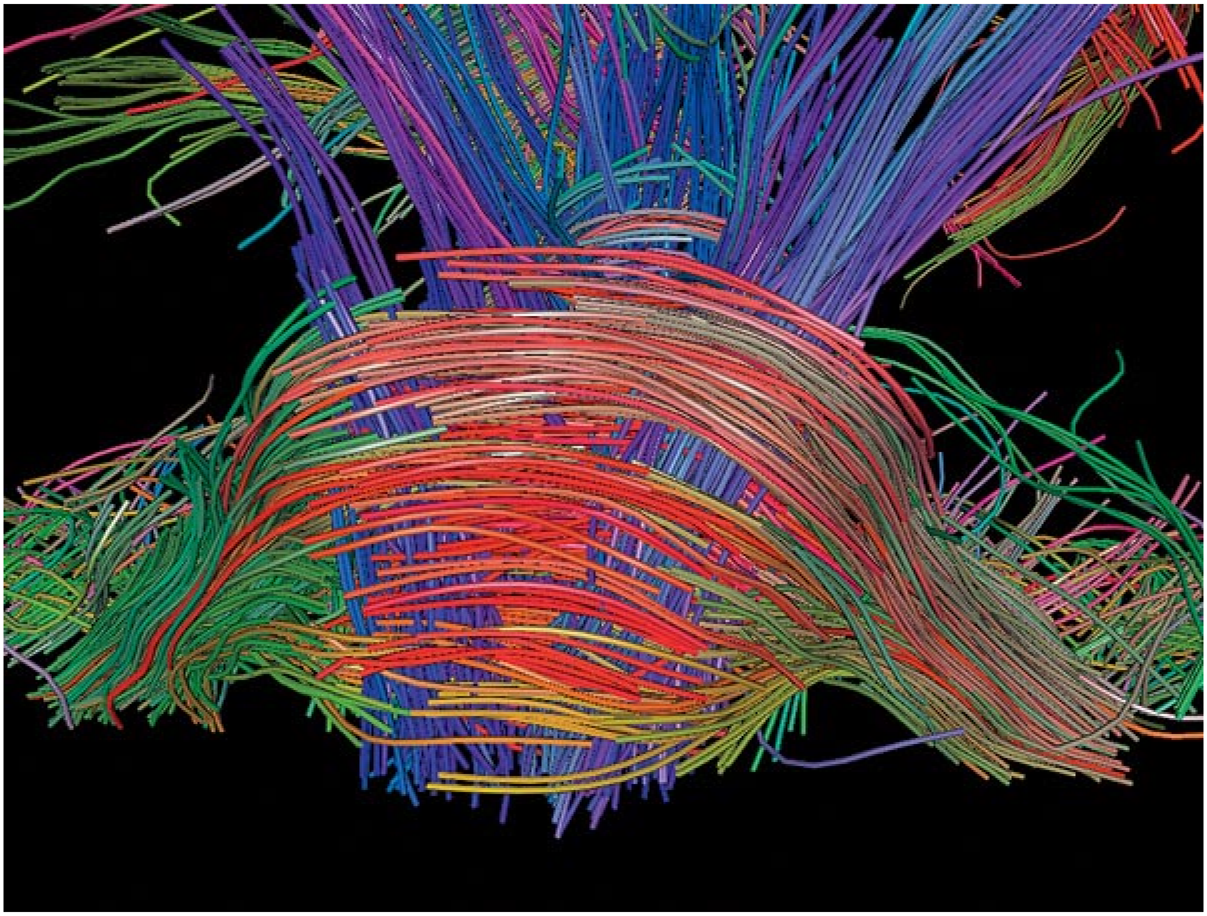
Images by Van Wedeen, Ruopeng Wang, Jeremy Schmahmann, and Guangping Dai of the MGH Martinos Center for Biomedical Imaging in Boston, MA; Patric Hagmann of EPFL and CHUV, Lausanne, Switzerland; and Jon Kaas of Vanderbilt University, Nashville, TN.

Mapping Diffusion
Neural fibers in the brain are too tiny to image directly, so scientists map them by measuring the diffusion of water molecules along their length. The scientists first break the MRI image into "voxels," or three-dimensional pixels, and calculate the speed at which water is moving through each voxel in every direction. Those data are represented here as peanut-shaped blobs. From each shape, the researchers can infer the most likely path of the various nerve fibers (red and blue lines) passing through that spot.

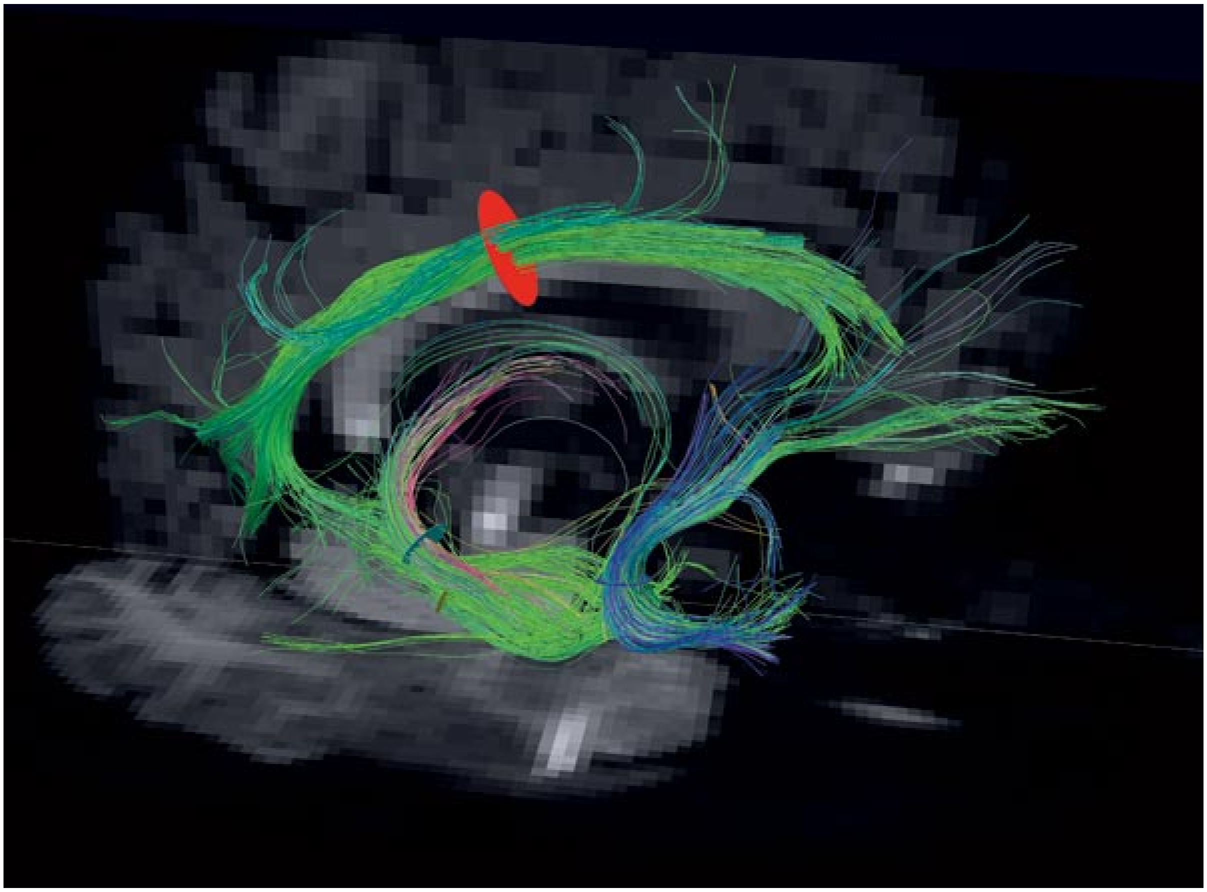




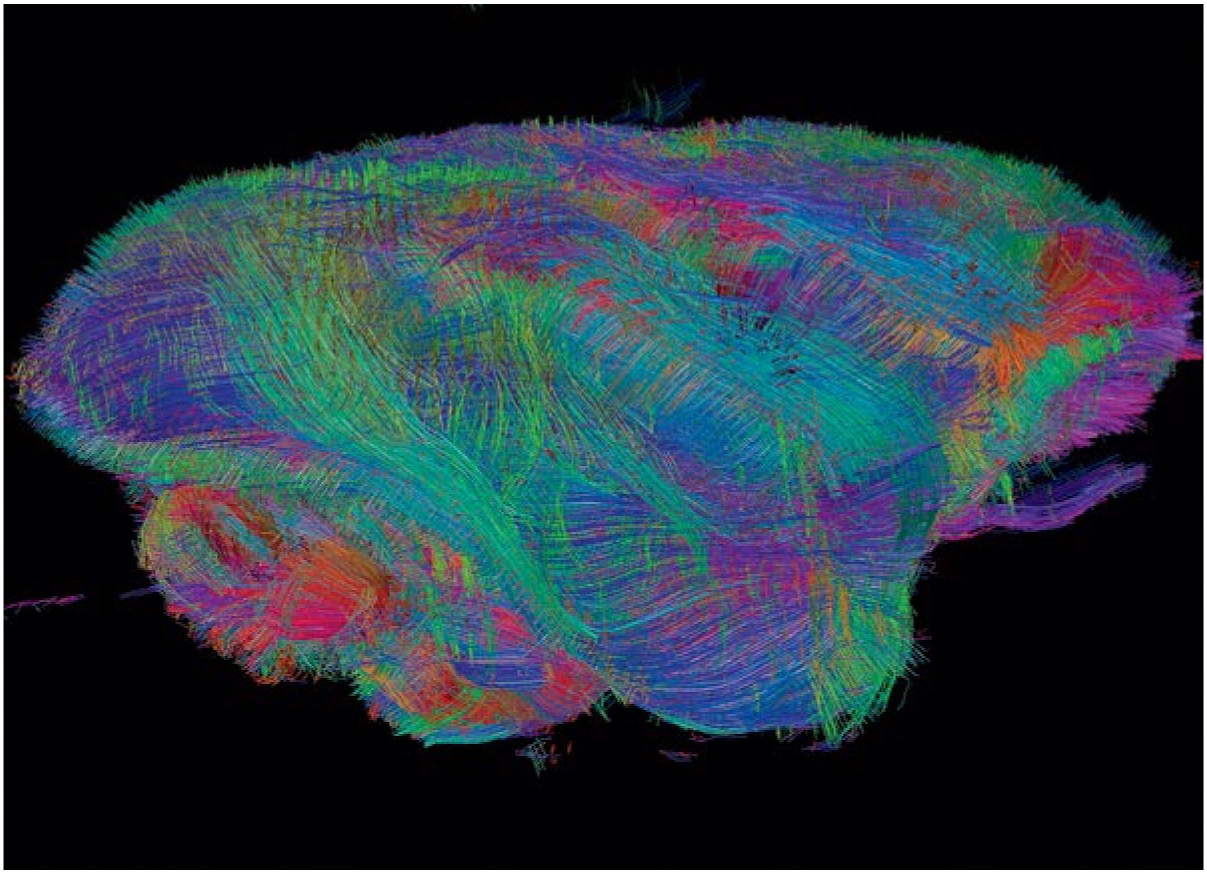
The result is a detailed diagram like that of the brain stem shown here.



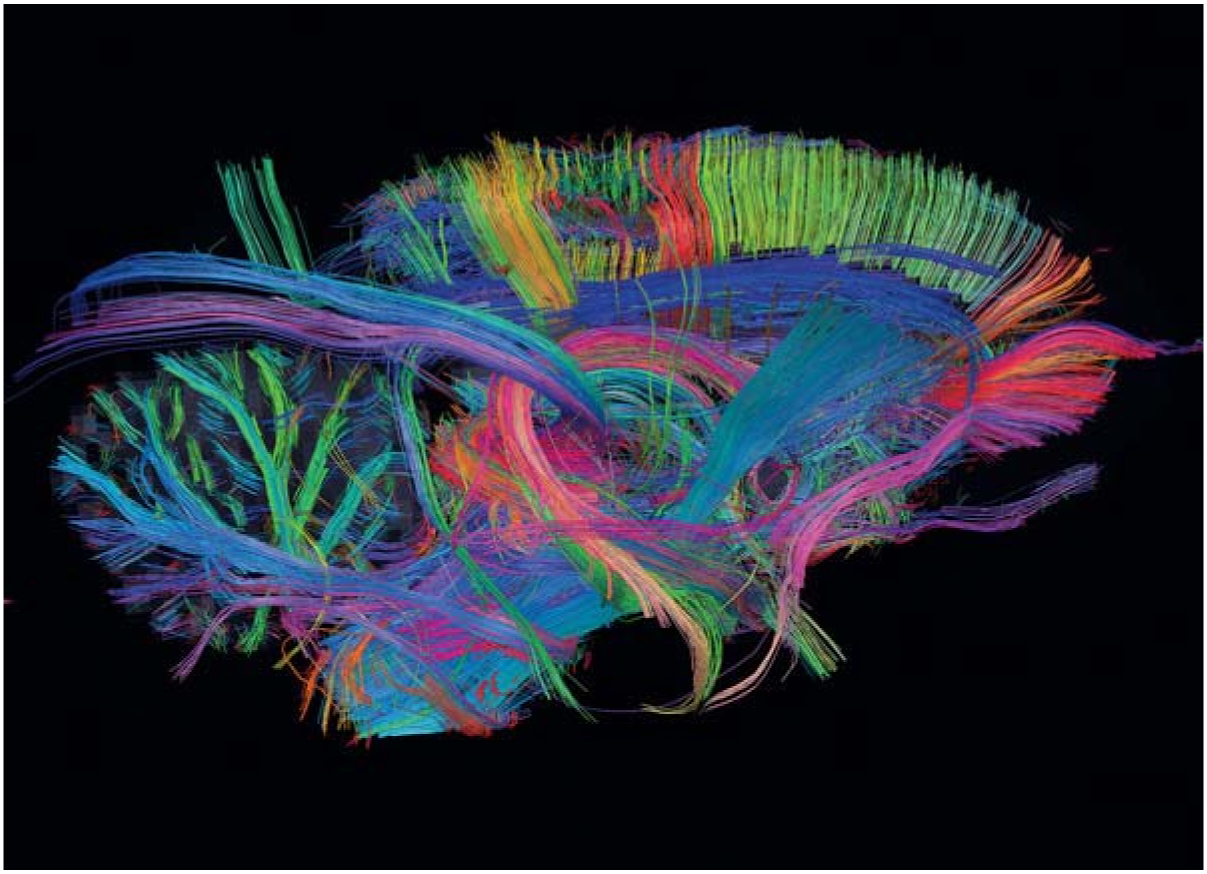
Emotion Control
To study specific circuits in the brain, scientists can isolate a subset of fibers. The circuit shown below represents the core of the human limbic system, which plays a central role in emotion and memory. The thick green bundle enclosed by the red circle is the cingulum bundle, which connects different parts of the cortex. The C-shaped blue fibers to the right, called the uncinate fasciculus, connect the temporal lobe, which regulates language and memory, with the frontal lobe, an area involved in higher executive function and planning. Damage to this circuit can result in the inability to form new memories and the loss of emotional control.



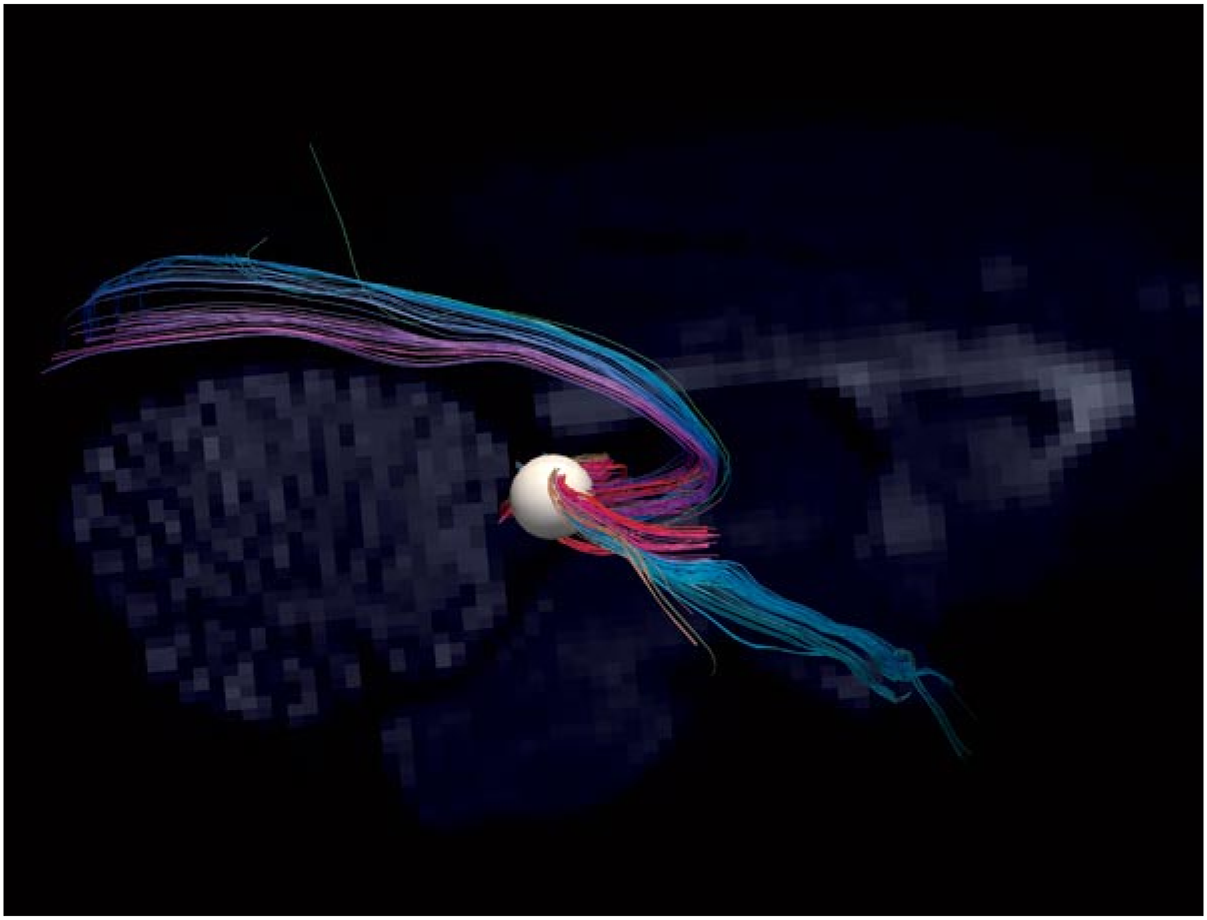
A Long Road
The brain of an owl monkey is shown here at increasing levels of detail: the complete brain,



a subset of fibers,



and the isolated optic tract, which relays visual signals from the eyes to the visual cortex. In the image of the optic tract, the blue lines at lower right represent nerve fibers connecting the eyes to the lateral geniculate nucleus (marked by the white ball), a pea-size ball of neurons that acts as a relay station for visual information. Those signals are then sent to the visual cortex, at the back of the head, via the blue and purple fibers that arc across the brain.



Interactive Tools
The three tools below and on the next two pages show data gathered in different ways from a living human volunteer. In each image, the brain is viewed from the back at a three-quarter profile, with the volunteer's eyes pointed back and toward the right.

/articlefiles/0811Brain/video_player_TV01.swf

In this interactive tool, only the fibers that intersect a given vertical plane are shown in each still image. Visualizing only a subset of the brain's densely packed neural fibers allows individual networks to be studied in greater detail. Users can either click on the arrow in the center of the image to view a movie that moves the plane through the brain from left to right, or they can move manually through the brain using the cursor below. Neurosurgeons sometimes use this type of visualization when searching for signs of a tumor.

/articlefiles/0811Brain/video_player_TV02.swf

Just as most roads in the United States are local streets rather than interstate highways, most connections in the brain are short range. In this interactive tool, fibers are removed based on their length. As the cursor moves right, progressively longer fibers are subtracted from the visualization.

The red and orange fibers in the lower left quadrant of the image, which begin to disappear when the cursor is at its midpoint, are part of the brain's sensory association pathways, integrating visual auditory information, for example. The last fibers to remain--the blue C-shaped fibers running horizontally across the middle of the image--are part of the cingulum bundle, which runs from the prefrontal cortex, which is involved in planning and higher cognitive function, to the parietal cortex, which is mainly involved in synthesizing sensory information.

/articlefiles/0811Brain/video_player_TV03.swf

This visualization begins with a view of the brain's right hemisphere, then rotates clockwise. A head-on view is shown about one-fifth of the way through. This image shows only a subset of fibers that intersect a vertical plane in the left hemisphere of the brain. Because most connections in the brain are short range, the left hemisphere appears more densely packed than the right; few fibers travel from their origins in the left hemisphere to the right.