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10 NEW WAYS TO PEER INTO YOUR BRAIN page 42
Artistry abounds in these 10 maps of the human mind
By Ann Chin and Sandra Upson

With 100 billion neurons and trillions of synapses, your brain spins neural webs of staggering complexity. It propels you to breathe, twitch, and butter toast, and yet we remain largely ignorant of how the brain does even these simple tasks—let alone how it stirs up consciousness.

To peer inside this three-pound lump of flesh, scientists manipulate a subtle trait of the body—its susceptibility to magnetic fields. Magnetic resonance imaging (MRI) has exposed the brain in stunning anatomical detail, and a sibling method, functional magnetic resonance imaging (fMRI), has offered insight into the mind at work. Here we explore how neuroscientists are using these methods to reveal new dimensions of the human brain.

HIGH-DEFINITION FIBER TRACTOGRAPHY
To define the lines in the image on the opposite page, an MRI machine charts the motion of water molecules at thousands of places in the brain, revealing the presence of fiber bundles, or tracts.

A major recent advance in diffusion imaging came from resolving how nerve fibers cross. The dragonfly-shaped elements shown at the near left indicate the orientations of two or more intersecting fibers, whereas the minnowlike ellipsoids signify one dominant fiber path.
MAGNETIC RESONANCE IMAGING

An MRI scanner harnesses the magnetic properties of hydrogen atoms to produce images of the body’s interior. A magnetic field first causes the billions of hydrogen atoms in the human body to point in a single direction. The scanner then administers short pulses of energy that force the atoms to slide out of alignment. When they return to their original positions, they do so at different rates, creating magnetic signatures for various tissues. At the right, a scan of a brain after a stroke reveals a region of dead tissue, shown in red.

Functional MRI scans, which form the basis of the images on the opposite page, reflect the magnetism of blood vessels. When neurons spring into action, they consume energy, which increases the amount of blood traveling to them. The most widespread technique measures the differences in the iron content of oxygen-rich and oxygen-poor blood.
MAGNETOENCEPHALOGRAPHY

When neurons fire, they generate tiny magnetic fields. By surrounding the brain with extremely sensitive magnetic field detectors, neuroscientists can record that neural activity. Combining magnetoencephalography (MEG) data with an MRI view of the same brain provides anatomical detail. Because MEG directly observes neurons’ behavior, as opposed to blood flow, it can capture brain events by the millisecond, as compared with a few seconds for an fMRI scan.

FUNCTIONAL CONNECTIVITY MRI

Unlike diffusion imaging, which traces physical links, these maps display how brain regions interact. Certain areas share a long history of working together to complete a task, even though they may not be directly connected by nerve fibers. Those functionally related regions also tend to activate in tandem when the brain is resting. The two images here were compiled from fMRI scans of a person at rest.

The diagram at the top left shows how fMRI images can predict a brain’s age. The color of a sphere reflects its function, such as processing sensory data, and its size reflects its predictive power. The thickness of a line, which links interacting areas, shows how well the strength or weakness of that connection predicts a certain age. Orange links grow stronger as brains age, whereas light green ones weaken with time.

The activity of brain areas changes constantly according to distinct patterns. The image at the bottom condenses those fluctuating dynamics into one figure. Here the yellow region surrounding the small green sphere, believed to be involved in visual processing, activates in synchrony with areas colored yellow and red. When the area around the green sphere revs up, green and purple regions are much less active, and vice versa.

(The Authors)

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**MAGNETIC RESONANCE ANGIOGRAPHY**

This technique is a type of MRI used to study blood vessels. Sometimes a liquid dye injected into the bloodstream helps the MRI machine register blood flowing through veins and arteries more vividly. The dark blue spot indicates an aneurysm in the brain of a 68-year-old woman.

**GENE EXPRESSION MAPPING**

The Allen Human Brain Atlas catalogues the genes at work in the brain. Here the dots show the expression of gpr88, a gene that is highly active in the striatum. This area, in purple, is involved in movement. The light blue and yellow clouds denote the cerebellum and the thalamus, respectively. The spheres’ colors reveal activity levels: expression is low for blue dots and high for red ones. Gpr88 is considered a potential drug target for treating disorders such as Parkinson’s disease.
Charting how blood flows through the brain is a mainstay of modern neuroscience and is key to elucidating the organ’s structure. Microscopic blood vessels, shown here with the aid of a scanning electron microscope, supply the brain with energy and nutrients. The blood vessel at the top branches into tiny capillaries that distribute blood through the rest of the brain.