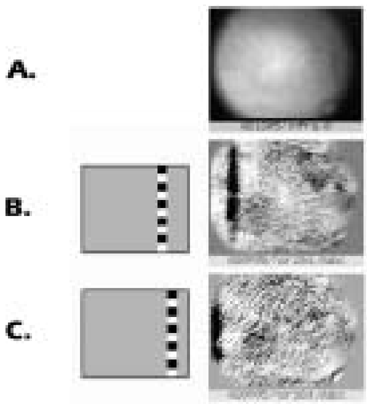
Daniel Y. Ts'o, Ph.D.

How the Neocortex Is Organized

Nearly half of the human brain is involved with vision. The neocortex, the convoluted mass that comprises most of the brain, is like an array of highly organized computers. One area deals with emotion while other areas deal with smell, motor activity, vision, and other functions. Although these brain areas are similar in structure, they differ in the kinds of information they receive and where they send their output.



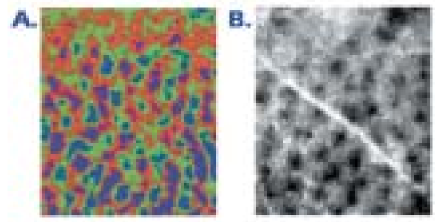
A strip of retina activated by a counterflickering checkerboard vertical bar stimulus.

A. Infrared image of the retina before stimulation. Note the optic disk in the lower right corner.
B. Left: Visual stimulus, a flickering vertical bar of squares (checks). Right: The optical imaging response to the vertical stimulus on the left.
C. Left: Visual stimulus, a vertical bar of checks positioned to the right of the bar in B. Right: Optical imaging response to the vertical bar of checks on the left. Note that the response in the retina moves further to the left as the stimulus moves to the right. This is because the eye inverts the visual stimulus.

Dr. Daniel Ts'o is studying how the neocortex is organized and how this organization relates to various functions. He uses anatomical tract tracing, electrophysiology, and optical imaging techniques to study activities of individual brain cells and groups of cells. For example, he has used optical imaging to distinguish groups of neurons that process color vision from groups of neurons that process form vision.

Dr. Ts'o studied under Dr. Torsten N. Wiesel, who shared the 1981 Nobel Prize in Medicine with Drs. David S. Hubel and Roger Sperry for discoveries in how information is processed in the visual system.

Scientists have identified some 50 different visual areas in the brain. Focusing on areas V1, V2, and V4, Dr. Ts'o is studying how these three particular areas function together as a series of stages. His ultimate goal is to find out why we need so many areas to process visual information. This question is important not only for our understanding of how the brain works, but also for its important clinical implications. For example, injury to one part of the cortex can impair color vision while leaving all other functions intact. Similarly, injury to another part of the cortex may destroy only the ability to perceive form or motion. A person with cerebral achromatopsia loses color vision due to an injury in the cortex, whereas in common "color blindness," the loss of color vision is due to an absence of certain cones in the retina.



Organization of color-sensitive cells in the brain.

A. Color cells in the brain (blue patches) receive input from just one eye. But the bands of non-color cells from the left eye (red) overlap with those of the right eye (green), indicating binocular input to these cells. Non-color cells (red) receive input from the left eye (red bands) or right eye (green bands).

B. Visualization of the same patches of color cells by stimulation with colored patterns. Such stimulation increases the cells' use of oxygen and blood, as shown by darkening of the patches. The surrounding lighter regions contain cells involved in form vision rather than color vision. Each color cell patch is about 0.3 mm in diameter on the surface of the brain.

Dr. Ts'o is also using optical imaging to study the retina. This technique will allow ophthalmologists to non-invasively detect damage to the retina before symptoms occur in diseases such as glaucoma. He plans to develop a similar technique for use during brain surgery. Since all areas of the brain look similar, neurosurgeons cannot always easily distinguish by sight the parts of the brain associated with motor function from the parts associated with senses. Since accidental damage to motor function can cause paralysis, a rapid and reliable method to distinguish critical motor-related areas from less important sensory areas will help neurosurgeons to avoid accidentally damaging motor areas during surgery.

Dr. Ts'o receives research funding from the National Eye Institute and the National Institute of Biomedical Imaging and Bioengineering. He has received the Office of Naval Research Young Investigator Award, McKnight Scholars Award, and Whitaker Biomedical Engineering Award. He collaborates with Dr. Barlow of CVR and scientists at Harvard, Rockefeller, University of Iowa, and Johns Hopkins Universities; the Weizmann Institute of Science in Israel; and the Kestrel Corporation in New Mexico.

He has contributed chapters to four books and has taught at Harvard University, Baylor College of Medicine, and State University of New York. His research has been published in *Science*, *Proceedings of the National Academy of Sciences*, *Proceedings of the Society of Photo-Optical Instrumentation Engineers (Medical Imaging)*, *Journal of Neurophysiology*, *Journal of Neuroscience*, *Vision Research*, and *Annual Review of Physiology*. He serves on the editorial board of *Vision Research*.