Brain changes linked to phantom-limb pain

For more than 100 years, physicians have published accounts of people who perceive an amputated arm or leg as if it were still there. Many amputees feel burning, cramping, or shooting pains in these phantom limbs, often at specific anatomical points. Reasons for the existence of these eerie, sometimes excruciating sensations remain uncertain, and medical attempts to ease phantom-limb pain usually fail.

A new study suggests that the most severe pain of this type occurs in people in whom, after amputation, an area of the brain that formerly handled sensations from the severed limb undergoes extensive reorganization. Large-scale remodeling of this strip of sensory tissue may somehow alter the neural circuits involved in pain, thus resulting in phantom-limb pain, propose Herta Flor, a psychologist at Humboldt University in Berlin, and her colleagues.

"This is the first evidence that there is a central nervous system correlate of phantom-limb pain," says study coauthor Edward Taub, a psychologist at the University of Alabama at Birmingham. "It's one big piece of the jigsaw puzzle in understanding this phenomenon, but it's not the whole story."

Flor's team recruited 12 men and 1 woman, ranging in age from 27 to 73, who had had an arm amputated at least a year before the study. The scientists measured magnetic responses in participants' brains to light pressure on the intact thumb and pinkie finger, as well as on the left and right sides of either the lower lip or the chin. The researchers then mapped areas of magnetic activity onto a reconstructed image of the somatosensory cortex, a nerve impulse center for various body parts.

Since the left and right hemispheres of the brain regulate opposite sides of the body, stimulating the fingers sparked magnetic responses only in the hemisphere opposite the intact limb. A mirror image of the finger activation sites was then projected onto the hemisphere opposite the amputated arm.

This technique provides a good estimate of the location of somatosensory sites for an absent limb, Taub argues. Prior magnetic imaging work by another research team had found little variation in the location of corresponding parts of the somatosensory cortex in the hemispheres of nonamputated individuals.

Cortical reorganization, evidenced by substantial encroachment of sensory areas for the face into regions previously reserved for the amputated fingers, was most pronounced in the eight participants who suffered from phantom-limb pain, Flor's group reports in the June 8 NATURE. The greater the cortical shift, the more phantom-limb pain amputees reported.

The new data support earlier studies that charted cortical reorganization in monkeys after researchers cut nerve impulses to the animals' limbs.

Nervous system damage may trigger a strengthening of connections between somatosensory cells as well as the formation of new ones, Taub suggests. In some cases, an imbalance of pain messages from other brain areas may occur, leading to phantom-limb pain, he theorizes.

Or phantom-limb pain may result from a remapping of somatosensory areas that accidentally infringes on nearby pain centers, contends Vilayanur S. Ramachandran, a neurologist at the University of California, San Diego. Ramachandran and his coworkers reported last year that marked somatosensory reorganization had occurred in two amputees.

Further research with the more precise brain-imaging methods now available is needed to confirm the substantial cortical changes reported in adult amputees, notes Tim P. Pons, a neuroscientist at Wake Forest University's Bowman Gray School of Medicine in Winston-Salem, N.C. *— B. Bower*

Balancing California's quake budget

Seismologists rarely bear good news, but residents of Southern California might welcome the iconoclastic views of David D. Jackson and Yan Kagan of the University of California, Los Angeles.

At a meeting of the American Geophysical Union in Baltimore last week, Jackson and Kagan attacked a central assumption of seismic forecasting—the idea that any individual fault segment repeatedly produces earthquakes of a characteristic size. If their criticism proves valid, the Los Angeles region may not suffer a widely expected surge in the frequency of magnitude 6.5 to 7.0 earthquakes, tremors similar in size to those that hit Northridge, Calif., and Kobe, Japan, recently.

"The good news is that perhaps we haven't just been lucky with the magnitude 7.0s. Perhaps the historic rate of earthquakes is about right, and that's what we should expect in the future," said Jackson.

This optimistic outlook does come with a price, warned the researchers. If Southern California faults fail to produce numerous magnitude 7.0 tremors, they must eventually—within a few centuries—serve up a great 8.0 to 8.5 earthquake, much larger than what most scientists have considered possible.

The UCLA seismologists reached this conclusion after testing studies that used the characteristic earthquake hypothesis for hazard forecasts. According to the hypothesis, geologists can deduce the largest earthquake possible on a particular fault segment by determining the segment's length and how much it moved in previous quakes. For the approach to work, fault segments must generate similar earthquakes over and over.

Jackson and Kagan analyzed four studies focusing on Southern California and the Pacific region. In all cases, the theory called for more quakes than had actually occurred.

Jackson played a key role in one of these studies, issued by the Southern California Earthquake Center (SCEC) in January. The SCEC report concluded that Southern California should have experienced twice as many magnitude 7.0 and larger quakes since 1850 as it has (SN: 1/21/95, p.37).

To explain that discrepancy, Jackson and Kagan reasoned that the characteristic earthquake hypothesis sets too low a limit on the size of potential tremors. For instance, the SCEC report included the possibility of earthquakes as large as magnitude 7.8, the size of the last Big One in Southern California, in 1857. If even stronger quakes strike the region, that would reduce the number of smaller ones—because it takes 30 magnitude 7.5 tremors to equal the energy of a magnitude 8.5 jolt.

Jackson and Kagan envision fault segments acting randomly instead of producing characteristic earthquakes. Sometimes several segments join together to create a great quake, other times they break independently. The researchers even question whether faults have identifiable segments. To test their theory, Jackson and Kagan plan to look at quake frequencies in other parts of the world.

Such arguments have not won over David P. Schwartz of the U.S. Geological Survey in Menlo Park, Calif., who formulated the characteristic earthquake hypothesis in the early 1980s. "The overall body of observations is in support of there being characteristic earthquakes," he says.

While Schwartz agrees that some fault segments can join to produce larger earthquakes, he maintains that most faults cannot produce the giant jolts called for by Jackson and Kagan. If Schwartz is right, regions such as Southern California cannot escape an increasingly shaky future.

— R. Monastersky