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Neuroplasticity: The Brain's Ability to Change Itself

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Neuroplasticity refers to the brain's ability to reorganize itself, forming new connections and pathways in response to neurological damage, learning new skills, or creating new memories. This process occurs via increases in the number and density of neurons, dendrites, synapses, and proteins essential to the survival of nerve cells. The brain is constantly laying down new pathways for communication and rearranging existing ones. Connections that are inefficient or infrequently used fade away, while those that are frequently traversed will be strengthened. As many as half of the synapses in the nervous system have the capacity to grow, connect, disconnect, and reconnect to each other in response to life experiences.

Although the concept of neuroplasticity dates back at least as far as 1890 when William James first proposed it in *The Principles of Psychology,* it was largely ignored for the first half of the 20th century. Jerzy Kornorski, a Polish neurophysiologist, was most likely the first person to use the term "neural plasticity." During the 1960s David Hubel and Torsten Wiesel at Johns Hopkins received the Nobel Prize for their pioneering work on "critical periods" of development in the brains of newborn kittens. Their work demonstrated the existence of neuroplasticity by showing that when one eye was deprived of visual input during a "critical period" (the third to eighth week of life), the brain region responsible for processing information from that eye failed to develop and began to process information from the open eye—evidence that the brain found a way to rewire itself.

Well into the latter part of the 20th century, it was believed that neuroplasticity in most areas of the brain was only possible during infancy and early childhood. However, recent research conducted by Michael Merzenich, Ph.D. (Professor Emeritus, University of California San Francisco) and others has demonstrated that the human brain has the capacity to reorganize itself throughout the lifespan.

Four types of neuroplasticity (functional map expansion, sensory reassignment, compensatory masquerade, and mirror region takeover) have been identified by Jordan Grafman, chief of the Cognitive Neurosciences Section, National Institute of Neurological Disorders and Stroke. In the case of "functional map expansion," daily activities determine the extent to which the boundaries between brain regions are committed to various tasks. An example of "sensory reassignment" would be a situation wherein one sensory modality (vision for example) is damaged and, in response, another sensory modality (touch for example) contributes inputs into the cortical space previously committed to the damaged modality. "Compensatory masquerade" applies in situations where the brain switches from using one type of strategy to using a different strategy. "Mirror region takeover" describes a situation in which a region of one hemisphere is damaged, and the corresponding region in the opposite hemisphere takes over the function of the damaged region to the extent possible.

Brain reorganization takes place through a variety of mechanisms. Undamaged brain cells (neurons) may grow nerve endings to reconnect with those that were damaged or severed. New nerve endings may sprout from undamaged neurons and connect with other undamaged nerve cells, forming new neural pathways to accomplish a needed function. The conduction speed of neuronal electrical impulses can be enhanced by increasing the myelin sheath that covers axons. Stimulation through activity is required for reorganization of this type to take place. A variety of studies have demonstrated that the brain can change in response to learning a new skill. When one becomes expert in a skill, the areas of the brain associated with that type of skill will grow. Some preliminary evidence from brain imaging studies indicates that behavioral therapy for such conditions as depression, anxiety and obsessive-compulsive disorder can cause measurable changes equivalent to those generated with medication treatment.

Treatment of motor and sensory deficits caused by stroke, one of the leading causes of disability in adults, has been quite limited. Pioneering work by Edward Taub resulted in development of the neuroplasticity-based treatment called Constraint-Induced Movement Therapy (CMT), which has generated marked return of function in partially paralyzed limbs by forcing patients to engage in "massed practice" using their damaged arms and incrementally increasing the difficulty level over time. When a person suffers a stroke, the brain map for an affected arm shrinks to about half its normal size. In one study, Taub and colleagues demonstrated that CMT initiated more than six years after a stroke doubled the size of the brain map that controlled hand movement. They found that neuroplastic changes occurred in both the damaged and the opposite hemispheres.

Numerous potential future applications of neuroplasticity are possible. As scientific research continues, new and more effective treatments for recovery from brain injury and neurological diseases will be developed. Advances in the treatment of cognitive disabilities like Attention-Deficit Disorder, dyslexia, and autism are likely to emerge. Breakthroughs are also likely in the treatment of psychiatric illnesses like schizophrenia, depression, anxiety, and anorexia.

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