



Brain Plasticity: What Is It?

Learning and Memory



Brain Plasticity--An Overview

What is *brain plasticity*? Does it mean that our brains are made of plastic? Of course not. Plasticity, or neuroplasticity, describes how experiences reorganize neural pathways in the brain. Long lasting functional changes in the brain occur when we learn new things or memorize new information. These changes in neural connections are what we call *neuroplasticity*.



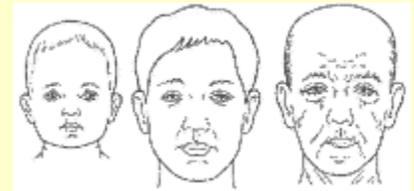
To illustrate the concept of plasticity, imagine the film of a camera. Pretend that the film represents your brain. Now imagine using the camera to take a picture of a tree. When a picture is taken, the film is exposed to new information -- that of the image of a tree. In order for the image to be retained, the film must react to the light and "change" to record the image of the tree. Similarly, in order for new knowledge to be retained in memory, changes in the brain representing the new knowledge must occur.

To illustrate plasticity in another way, imagine making an impression of a coin in a lump of clay. In order for the impression of the coin to appear in the clay, changes must occur in the clay -- the shape of the clay changes as the coin is pressed into the clay. Similarly, the neural circuitry in the brain must reorganize in response to experience or sensory stimulation.

Facts About Neuroplasticity

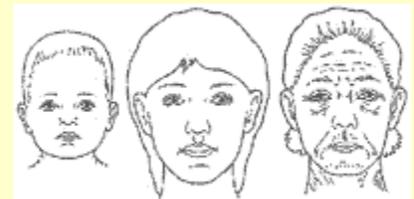
FACT 1: *Neuroplasticity includes several different processes that take place throughout a lifetime.*

Neuroplasticity does not consist of a single type of morphological change, but rather includes several different processes that occur throughout an individual's lifetime. Many types of brain cells are involved in neuroplasticity, including neurons, glia, and vascular cells.



FACT 2: *Neuroplasticity has a clear age-dependent determinant.*

Although plasticity occurs over an individual's lifetime, different types of plasticity dominate during certain periods of one's life and are less prevalent during other periods.



FACT 3: *Neuroplasticity occurs in the brain under two primary conditions:*

1. During normal brain development when the immature brain first begins to process sensory information through adulthood (developmental plasticity and plasticity of learning and memory).
2. As an adaptive mechanism to compensate for lost function and/or to maximize remaining functions in the event of brain injury.

FACT 4: *The environment plays a key role in influencing plasticity.*

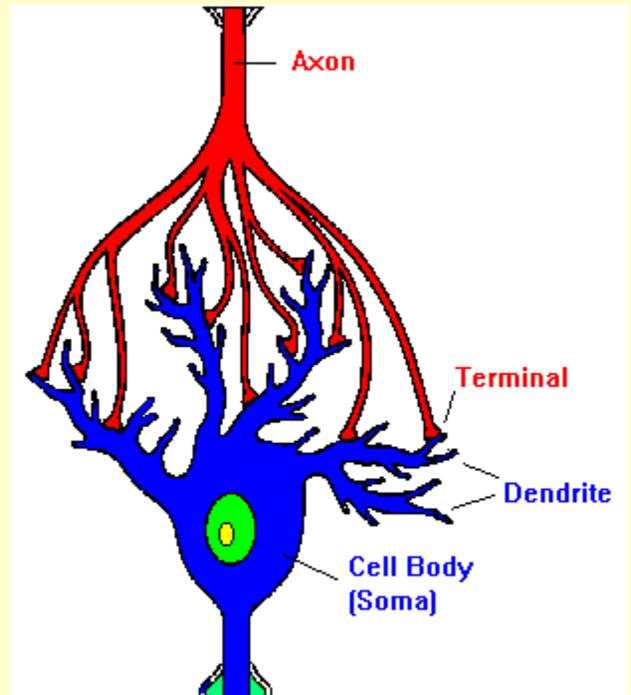
In addition to genetic factors, the brain is shaped by the characteristics of a person's environment and by the actions of that same person.

Developmental Plasticity: Synaptic Pruning



Gopnick et al. (1999) describe neurons as growing telephone wires that communicate with one another. Following birth, the brain of a newborn is flooded with

information from the baby's sense organs. This sensory information must somehow make it back to the brain where it can be processed. To do so, nerve cells must make connections with one another, transmitting the impulses to the brain. Continuing with the telephone wire analogy, like the basic telephone trunk lines strung between cities, the newborn's genes instruct the "pathway" to the correct area of the brain from a particular nerve cell. For example, nerve cells in the retina of the eye send impulses to the primary visual area in the occipital lobe of the brain and not to the area of language production (Wernicke's area) in the left posterior temporal lobe. The basic trunk lines have been established, but the specific connections from one house to another require additional signals.



Over the first few years of life, the brain grows rapidly. As each neuron matures, it sends out multiple branches (axons, which send information out, and dendrites, which take in information), increasing the number of synaptic contacts and laying the specific connections from house to house, or in the case of the brain, from neuron to neuron. At birth, each neuron in the cerebral cortex has approximately 2,500 synapses. By the time an infant is two or three years old, the number of synapses is approximately 15,000 synapses per neuron (Gopnick, et al., 1999). This amount is about twice that of the average adult brain. As we age, old connections are deleted through a process called *synaptic pruning*.

Synaptic pruning eliminates weaker synaptic contacts while stronger connections are kept and strengthened. Experience determines which connections will be strengthened and which will be pruned; connections that have been activated most frequently are preserved. Neurons must have a purpose to survive. Without a purpose, neurons die through a process called apoptosis in which neurons that do not receive or transmit information become damaged and die. Ineffective or weak connections are "pruned" in much the same way a gardener would prune a tree or bush, giving the plant the desired shape. It is plasticity that enables the process of developing and pruning connections, allowing the brain to adapt itself to its environment.

Plasticity of Learning and Memory

It was once believed that as we aged, the brain's networks became fixed. In the past two decades, however, an enormous amount of research has revealed that the brain never stops changing and adjusting. Learning, as defined by Tortora and Grabowski (1996), is the ability to acquire new knowledge or skills through instruction or experience. Memory is the process by which that knowledge is retained over time. The capacity of the brain to change with learning is plasticity. So how does the brain change with learning? According to Durbach (2000), there appear to be at least two types of modifications that occur in the brain with learning:



1. A change in the internal structure of the neurons, the most notable being in the area of synapses.
2. An increase in the number of synapses between neurons.

Initially, newly learned data are "stored" in short-term memory, which is a temporary ability to recall a few pieces of information. Some evidence supports the concept that short-term memory depends upon electrical and chemical events in the brain as opposed to structural changes such as the formation of new synapses. One theory of short-term memory states that memories may be caused by "reverberating" neuronal circuits -- that is, an incoming nerve impulse stimulates the first neuron which stimulates the second, and so on, with branches from the second neuron synapsing with the first. After a period of time, information may be moved into a more permanent type of memory, long-term memory, which is the result of anatomical or biochemical changes that occur in the brain (Tortora and Grabowski, 1996).

Injury-induced Plasticity: Plasticity and Brain Repair

During brain repair following injury, plastic changes are geared towards maximizing function in spite of the damaged brain. In studies involving rats in which one area of the brain was damaged, brain cells surrounding the damaged area underwent changes in their function and shape that allowed them to take on the functions of the damaged cells. Although this phenomenon has not been widely studied in humans, data indicate that similar (though less effective) changes occur in human brains following injury.

They said it!



"The principal activities of brains are making changes in themselves."
--Marvin L. Minsky (from *Society of the Mind*, 1986)

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