[1] The newsletter title has been changed from **Aphasia Insights** to **Plasticity Insights** to encompass brain function and plasticity as the foundation of all learning as well as recovery.

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"From every act of memory, every exercise of bodily aptitude, every habit, recollection, train of ideas, there is a specific grouping or coordination of sensation and movement, by virtue of specific growth in cell junctions" (Bain, 1873).

Bain, Alexander (Scottish Philosopher, 1808-1903)
Mind and Body: The Theories of Their Relation. New York: D. Appleton & Company (1873).

Aphasia Nation, Inc. is committed to educating the wider public about stroke and aphasia and the "*Aim High for Aphasia!"* international Aphasia Awareness campaign.

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Plasticity Insights![1]

Donald O. Hebb: "Cells That Fire Together, Wire Together."

By Tom Broussard, Ph.D.

This is the next in a series of articles about the science and scientists behind the brain, stroke, aphasia, plasticity and recovery.

Donald Olding Hebb (July 22, 1904 – August 20, 1985) was a Canadian psychologist who was influential in the area of neuropsychology, where he sought to understand the function of cells (neurons) and the psychological processes of learning (Wikipedia).

Donald O. Hebb (1904 – 1985)

Donald Hebb was born in Chester, Nova Scotia. His parents were both medical doctors and adopted the ideas of Maria Montessori and home-schooled him. He graduated from Dalhousie University in 1925 and became a teacher at his old school in Chester. He completed his master's degree in psychology at McGill University in 1932 (Wikipedia).

He moved to Chicago under Karl Lashley at the University of Chicago and then followed him to Harvard University in 1935. He received his PhD from Harvard in 1936 and moved back to Montreal working under Wilder Penfield at the Montreal Neurological Institute (Wikipedia).

He followed Lashley again in 1942 who had become the director of the Yerkes National Primate Research Center, Orange Park, Florida and eventually returned to McGill University as professor and chairman of psychology. He worked with Penfield again with many of his doctorate students, including Mortimer Mishkin and Brenda Milner (Wikipedia).

Hebb's famous quote, "Cells that fire together, wire together" started with his master's thesis, *Conditioned and Unconditioned Reflexes and Inhibition* in 1932.

In the introduction, he wrote, "The purpose of this paper is to present a theory of the functioning of the synapse based on the experimental work of Sherrington and Pavlov, on reflexes and inhibitions" (Hebb, 1932).

He described the beginning of his theory of synaptic function and learning as, "an excited neuron tends to decrease its discharge to inactive neurons, and increase this discharge to any active neuron, and therefore to form a route to it, whether there are intervening neurons between the two or not. With repetition this tendency is prepotent in the formation of neural routes" (Hebb, 1932).

It took another 17 years to publish his magnus opus *The Organization of Behavior: A Neuropsychological Theory* (Hebb, 1949), originally titled, *On Thought and Behavior*, and described learning and behavior in terms of brain function.

It has become one of the most significant books in the history of biology along with Darwin's *On the Origin of Species* (1859/1979) with very similar approaches to selection and evolution. Darwin described "gene-based evolution creating the objects studied by biologists" while Hebb described "synapse-based evolution … studied by neurobiologists" (Adams, 1998).

As stated in *Hebb and Darwin* (1998), "It is because synapses are much more nimble and numerous than genes that mental adaptation is so much faster than physical adaptation" (Adams, 1998).

It is the unit of selection that undergoes the evolutionary process, genes for the world's human population, and synapses for the individual brain. Hebb's writing introduced the concepts of Hebb synapse, cell assembly, and phase sequence.

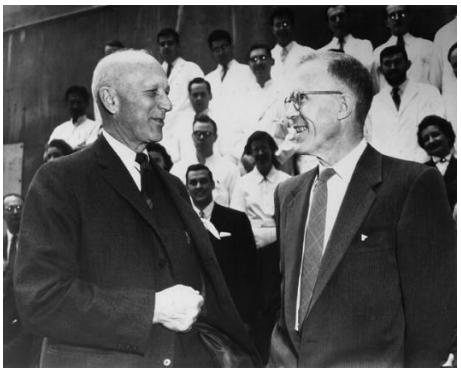
Hebb synapse - Hebb noted of the 'Hebb synapse'; "any two cells or systems of cells that are repeatedly active at the same time will tend to become 'associated' so that activity in one facilitates activity in the other" (Hebb, 1949).

William James in *The Principles of Psychology* said much the same thing, that cells "have once been aroused together or in immediate succession, any subsequent arousal of any one of them (whether from without or within) will tend to arouse the others in the original order. [This is the so-called law of association]" (James, 1890, pp.24).

Cell assembly - Hebb developed the cell assembly from discoveries by Lorente de Nó's work on reverberatory circuits and the "closed chain of neurons" (Lorente de Nó, 1938, 1939).

"The cell assembly is a group of neurons arranged as a set of closed pathways that have become connected with each other by the process of perceptual learning" (Brown, 2020).

It is a self-exciting set of neurons that fire from both external as well as internal 'reverberatory circuits' that become the basis of thought (Brown, 2020).



D. O. Hebb (right) and Wilder Penfield (left) in 1958 on the occasion of Hebb delivering the 24th Annual Hughlings Jackson lecture at the Montreal Neurological Institute.

The phase sequence - This is a temporal sequence of series of cell-assemblies which represents a chain of ideas, from sensation to thought. "Hebb outlined his concept of the phase sequence as a temporally organized pattern of cellular activity which could be identified with a train of thought…" (Brown, 2020).

Hebb helped explain brain function in terms of "associative connections between [assemblies] as threads of a tapestry are interwoven in making a larger pattern" of experience and education.

He remarked that "schooling is only an adjunct to the home and to the child's experience outside of school; for however good the school, it can hardly provide that variety of past experience that is required for effective thought."

As Hebb declared, "Possession of the capacity for thought makes us a thought-dominated species" and learning-dominated as a result (Hebb, 1980).

Signed: *The Johnny Appleseed of Aphasia Awareness*

The author is a three-time stroke survivor and has aphasia as a result of the strokes. He continues to recover his language skills.

He is Founder and President, Aphasia Nation, Inc., a non-profit organization whose mission is educating the wider public, national and international, about aphasia and plasticity, the foundation of all learning.

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