Medical Neuroscience | Tutorial Notes

Synaptic Plasticity: Hebb's postulate

Map to Neuroscience Core Concepts[1]

NCC2. Neurons communicate using both electrical and chemical signals.

NCC4. Life experiences change the nervous system.

NCC8. Fundamental discoveries promote healthy living and treatment of disease.

Learning Objectives

After study of today's tutorial, the learner will:

1. Characterize general cellular mechanisms for synaptic change.
2. State Hebb's postulate and discuss its relevance for neural plasticity.

Tutorial Outline

I. Introduction

   A. **plasticity**: the capacity of the nervous system to change

   B. general cellular mechanisms for synaptic change:

      1. neural activity triggers the activation of postsynaptic, second messenger systems
      2. the trigger is usually a specific alteration in the levels of intracellular calcium in the postsynaptic neuron
      3. Ca-dependent second messenger systems alter the activity of protein kinases (phosphorylate target proteins) and phosphatases (dephosphorylate target proteins)
      4. alterations in protein phosphorylation mediate the early stages of long-term synaptic plasticity (changes in phosphorylation induce changes in protein function)
      5. the more long-lasting changes in synaptic strength are brought about by alterations in gene transcription induced by second messenger systems

II. Hebb's postulate (see **Figure 8.18**[2])

   A. proposed by the Canadian psychologist Donald O. Hebb (1904-1985) in his influential text, *The Organization of Behavior* (1949)[3]

   B. the principles of the postulate

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[1] Visit **BrainFacts.org** for *Neuroscience Core Concepts* (©2012 Society for Neuroscience) that offer fundamental principles about the brain and nervous system, the most complex living structure known in the universe.

[2] Figure references to Purves et al., *Neuroscience, 5th Ed.*, Sinauer Assoc., Inc., 2012. [click here]

[3] Read more about D.O. Hebb by clicking here

1. *coordinated activity* of a presynaptic terminal and a postsynaptic cell would *strengthen* the synaptic connection between them
2. conversely, *uncoordinated activity* between synaptic partners would *weaken* their synaptic connections
3. in short, "***neurons that fire together, wire together***"

C. changes in synaptic strength (consistent with Hebb's postulate) are mediated by **long-term potentiation** (LTP) and **long-term depression** (LTD)

D. spike-timing dependent plasticity (STDP) (see **Figure 8.18**) explains how synaptic change can occur one spike at a time under physiological conditions in neural networks

1. synapses *strengthen* when presynaptic activity *precedes* postsynaptic activity by ~20 msec or less (= coordinated activity)
2. synapses *weaken* when presynaptic activity *follows* postsynaptic activity by up to ~40 msec (= uncoordinated activity)

III. From synaptic plasticity to circuit plasticity

A. given Hebb's postulate: *"neurons that fire together, wire together"*

1. this implies that change at the synaptic level can produces changes in the wiring patterns of neural circuits
2. synaptic change accumulates (one synapse at a time) throughout a network of interconnected neurons (recall that a typical cortical pyramidal neuron maintains about 2,000 synaptic connections with other neurons!)
3. with the strengthening, awakening, and weakening of synaptic connections, and the addition and deletion of synaptic connections, the net effect of firing or misfiring together can be wholesale change in the structure and function of network properties

Study Question

Hebb's postulate is accurately captured by the aphorism coined by my late, great Duke colleague, Larry Katz, when he proposed: *"neurons that fire together, wire together"*. This sounds similar to another aphorism that is often taken as an equally valid restatement of Hebb's postulate: *"use it or lose it"*. Today's study question is this: is *"use it or lose it"* an accurate expression that reflects the synaptic mechanism of neural plasticity?

A. yes

B. no

C. no one knows