Medical Neuroscience | Tutorial Notes

Synaptic Plasticity: spike timing-dependent plasticity

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. Discuss the importance of the timing of the postsynaptic response, relative to presynaptic activity, for synaptic plasticity.

TUTORIAL OUTLINE

I. Introduction

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

   C. 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. Spike-timing dependent plasticity (STDP) (see **Figure 8.18**[2])

   A. explains how synaptic plasticity can occur in the brain *one postsynaptic spike at a time*

      1. seldom do patterns of neural activity in real brain circuits resemble the artificial spike trains that were used in the classical studies of the LTP and LTD

[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]

2. so, for example, if real synapses seldom (if ever) experience brief trains of 500 Hz stimulation, how does plasticity (LTP) work?
3. STDP provides a framework for understanding how synaptic plasticity can occur (LTP in this case) without the need for brief, high-frequency trains of stimulation

B. mechanisms: precision timing matters!

1. synapses **strengthen** when presynaptic activity *precedes* postsynaptic activity by ~20 msec or less
    a. this sequence of "pre- before post", and the short interval between the two, implicates the presynaptic input in question as the principal source of depolarization that resulted in the generation of a postsynaptic action potential
    b. this regime is consistent with the Hebbian notion of "coordination" between pre- and post-synaptic activity (more on this in next tutorial)
    c. for sensory circuits, structured experience with the sensory environment (e.g., training) may provide one means for coordinating spatial and temporal patterns of activity
2. synapses **weaken** when presynaptic activity *follows* postsynaptic activity by up to ~40 msec
    a. this sequence of "post before pre-" implicates some other presynaptic input as the principal source of depolarization that resulted in the generation of a postsynaptic action potential
        i. remember that most neurons receives 1000s of synaptic input
        ii. this "post before pre-" sequence indicates that the postsynaptic neuron was driven to fire an action potential by some other input, not the input in question
    b. this regime is consistent with the Hebbian notion of "incoordination" between pre- and post-synaptic activity
3. note that the interval between pre- and post-synaptic neuron firing that leads to LTD is roughly twice the interval that leads to LTP
    a. this suggests that random firing will tend toward LTD and the weakening of synaptic connections
    b. thus, unstructured activity in sensory circuits would be expected to favor LTD over LTP

STUDY QUESTION

Which of the following conditions would result in long-term potentiation among connected pre- and post-synaptic elements?

A. presynaptic spike firing 200 msec before a postsynaptic spike
B. presynaptic spike firing 100 msec before a postsynaptic spike
C. presynaptic spike firing 10 msec before a postsynaptic spike
D. presynaptic spike firing 10 msec after a postsynaptic spike
E. presynaptic spike firing 100 msec after a postsynaptic spike
F. presynaptic spike firing 200 msec after a postsynaptic spike