Medical Neuroscience | Tutorial Notes

Synaptic Integration

MAP TO NEUROSCIENCE CORE CONCEPTS[1]

NCC2. Neurons communicate using both electrical and chemical signals.

LEARNING OBJECTIVES

After study of the assigned learning materials, the learner will:

1. Discuss the concepts, "excitatory postsynaptic potential" (EPSP) and "inhibitory postsynaptic potential" (IPSP), defining them in terms of the reversal potential for the postsynaptic current and the threshold for generating an action potential.
2. Describe how postsynaptic potentials can summate in space and time.

TUTORIAL OUTLINE

I. Overview of neurotransmitters
   - A. review mechanisms of chemical synaptic neurotransmission (see **Figure 5.3**[2])
   - B. two broad classes based on molecular size and chemical class (see **Figure 6.1**)

II. Excitatory and inhibitory post synaptic potentials (PSPs) (see **Figure 5.21**)
   - A. **excitatory post synaptic potentials** (EPSPs)
     1. postsynaptic potential that **increases** the probability that the postsynaptic neuron will generate an action potential
     2. E_{rev} for the ligand-gated conductance is *above* than threshold for firing an action potential
   - B. **inhibitory post synaptic potentials** (IPSPs)
     1. post synaptic potential **decreases** the probability that the post synaptic cell will generate an action potential
     2. E_{rev} for the ligand-gated conductance is *below* the threshold for firing an action potential
   - C. can the same neurotransmitter induce EPSPs and IPSPs? … *YES!*

[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]

1. whether a neurotransmitter is excitatory or inhibitory is determined by its reversal potential relative to threshold
2. E_{rev} is determined by the concentration gradient(s) of the permeant ion(s)
3. a change in concentration gradient(s) could shift E_{rev} to one side of threshold or the other
4. for some neurons at least, this happens in development as chloride pumps mature and intracellular chloride concentration falls
    a. thus, GABA is *excitatory* for many immature neurons in the brain because Cl^- concentration is high inside cells and low outside cells
    b. but, GABA is *inhibitory* for most if not all mature neurons because chloride pumps develop that reverse the gradient: Cl^- concentration becomes low inside of cells and high in extracellular spaces (see **Box 6D**)

III. Summation of post synaptic potentials (see **Figure 5.22**)

A. most synapses in the CNS produce very small post synaptic potentials (i.e., most EPSPs are a millivolt or less—obviously, not sufficient to depolarize the neuronal membrane to threshold for firing action potentials)

B. there are consequences of this fact:

1. the amplitude of postsynaptic depolarization is *not* what makes this potential an EPSP (see above)
2. the small size of most EPSPs means that there is ample room for strengthening (most synapses are far from their "ceiling" in terms of EPSP amplitude)
3. the small size of most EPSPs also means that should a synapse undergo weakening, it may become "silent" or may physically disappear
4. with very few exceptions (Purkinje neurons in the cerebellum, and some types of auditory neurons in the brainstem, being among the few), neurons in the CNS must **summate** excitatory input from many sources in order to achieve threshold and fire action potentials

C. because most neurons are innervated by 1000s of synapses, postsynaptic potentials from many synapses do indeed summate in *space* (e.g., on the same dendrite) and *time* (i.e., before concurrent PSPs decay)

D. whether the integrated sum of synaptic input causes a postsynaptic neurons to fire an action potential at any moment in time depends upon:

1. the number and strength of EPSPs converging on the neurons dendritic arbor (most excitatory inputs synapse on small protuberances emanating from dendrites called, "dendritic spines")
2. the number and strength of IPSPs converging on the neurons dendritic arbor and soma (most inhibitory inputs synapse on dendritic shafts and cell bodies, also called "somata")

STUDY QUESTION

Which of the following statements about **excitatory postsynaptic potentials** (EPSPs) in the central nervous system (CNS) is most accurate?

A. Multiple EPSPs arriving together at different locations on the dendritic tree will cancel each other out and the neuron will remain at rest.
B. By definition, the reversal potential of an EPSP is at or below the resting membrane potential.
C. The EPSPs in the central nervous system are much larger and much more likely to induce a postsynaptic action potential, as compared to endplate potentials at neuromuscular junctions.
D. Multiple EPSPs occurring very close together in time can summate and help bring a neuron to firing threshold.
E. EPSPs in the mature CNS are typically associated with GABAergic neurotransmission.