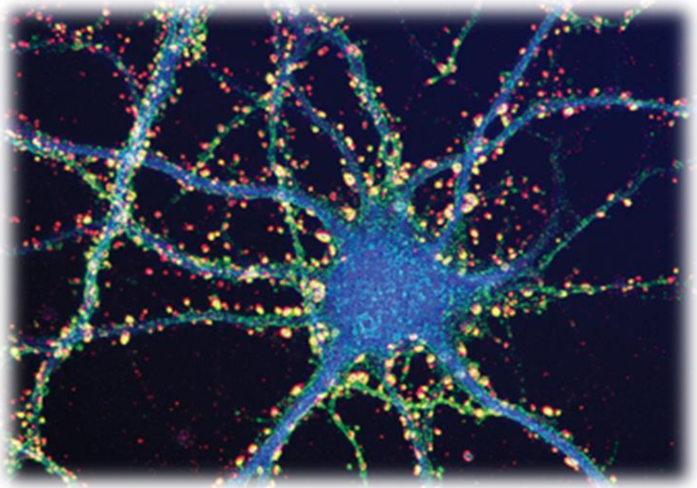

# SYNAPTIC INTEGRATION

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Nervous System


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- Most CNS neurons receive inputs from hundreds or thousands of synaptic terminals that activate different combinations of transmitter-gated ion channels and G-protein coupled receptors.

- The postsynaptic neuron integrates all these complex ionic and chemical signals to produce a simple form of output: **action potentials**.

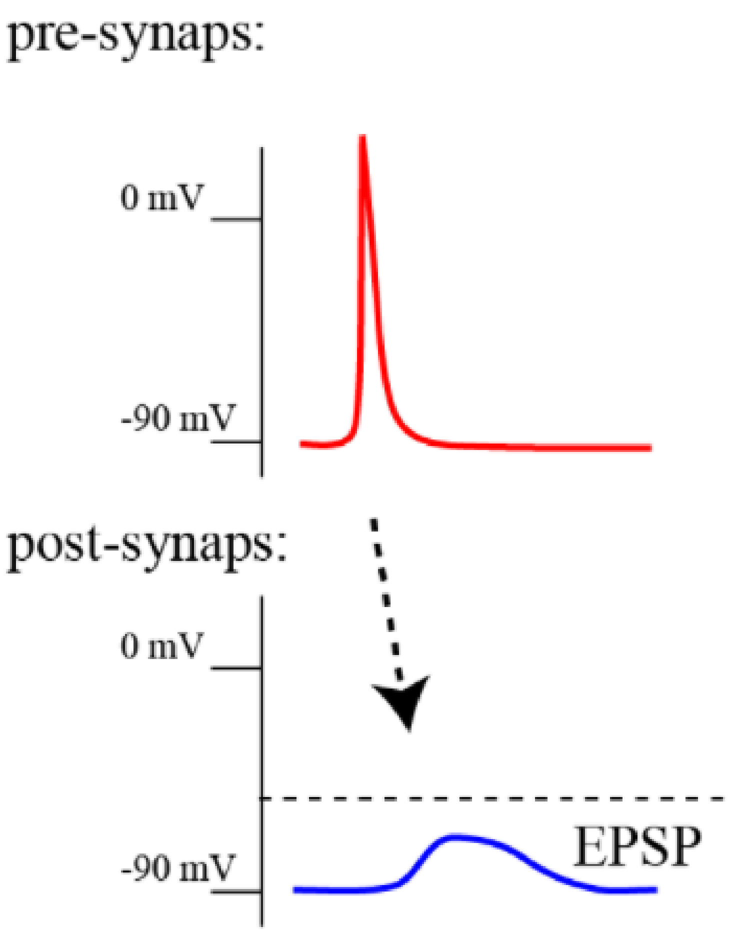
- The transformation of many synaptic inputs to a single neuronal output constitutes a **neural computation.**

# Synaptic integration

Process by which multiple synaptic potentials combine within one postsynaptic neuron

# The integration of EPSPs

- The most elementary postsynaptic response is the opening of a single transmitter-gated channel.
- Inward current through these channels depolarizes the postsynaptic membrane, causing the EPSP.
- A single EPSP is usually too small to trigger an action potential in a postsynaptic neuron



- The postsynaptic membrane of one synapse may have from **a few tens** to **several thousands** of transmitter-gated channels
- How many of these are activated during synaptic transmission depends mainly on how much NT is released.

- The elementary unit of neurotransmitter release is the contents of a single synaptic vesicle.
- Each vesicle contains about the same number of transmitter molecules (several thousand)
  - *Quantum*: The elementary unit of neurotransmitter release:content of a single synaptic vesicle
- The total amount of transmitter released is some multiple of this number.

Postsynaptic EPSPs at a given synapse are *quantized* ; they are multiples of an indivisible unit, the *quantum* which reflects the number of transmitter molecules in a single synaptic vesicle and the number of postsynaptic receptors available at the synapse.

- At many synapses, exocytosis of vesicles occurs at some very low rate in the absence of presynaptic stimulation.
- The size of the postsynaptic response to this spontaneously released neurotransmitter can be measured electrophysiologically.
- This tiny response is a **miniature postsynaptic potential** , often called simply a *mini*.

# Quantal analysis

- A method of **comparing** the amplitudes of **miniature** and **evoked PSPs**, can be used to determine how many vesicles release neurotransmitter during normal synaptic transmission.

- NMJ: Single action potential in the presynaptic terminal triggers the exocytosis of about 200 synaptic vesicles, causing an EPSP of 40 mV or more

At many CNS synapses, however, the contents of only a *single vesicle* are released in response to a presynaptic action potential, causing an EPSP of only a few tenths of a millivolt

# EPSP Summation

- A single EPSP is usually too small to trigger an action potential in a postsynaptic neuron
- Most neurons perform more sophisticated computations, requiring that many EPSPs add together to produce a significant postsynaptic depolarization.

# EPSP summation

Represents the simplest form of synaptic integration in the CNS.

Two types of summation

1. **Spatial summation**
2. **Temporal summation**

# Spatial Summation

The adding together of EPSPs generated simultaneously at many different synapses on a dendrite

# Temporal summation

The adding together of EPSPs generated at the same synapse if they occur in rapid succession, within about 1–15 msec of one another.

# The Contribution of Dendritic Properties to Synaptic Integration

# The effectiveness of an excitatory synapse in triggering an action potential, therefore, depends on

- How far the synapse is from the spike-initiation zone
- The properties of the dendritic membrane.

# The Spread of Current Through Neurons

- Passive spread of current

  $V_x = V_0 / e^{-x/\lambda}$

  λ is the "*length constant*"

  - At a distance λ, the membrane depolarization (V), is 37% of that at the origin
  - Actual length constants are 0.1 - 1.0 mm

- The length constant is an index of how far depolarization can spread down a dendrite or axon.
- The longer the length constant, the more likely it is that EPSPs generated at distant synapses will depolarize the membrane at the axon hillock.

The value of $\lambda$ depends on

- the resistance to current flowing longitudinally down the dendrite, called the **internal resistance (diameter of a dendrite and electrical properties of the cytoplasm)**
- the resistance to current flowing across the membrane, called the **membrane resistance (number of open membrane channels)**

# Whether or not an EPSP contributes to the action potential output of a neuron depends on several factors:

- Number of coactive excitatory synapses
- The distance the synapse is from the spike-initiation zone
- Properties of the dendritic membrane

# IPSPs and Shunting Inhibition

- Most synaptic inhibition is mediated by GABA-gated Cl- channels
  - $E_{Cl-}$ is -65 mV
  - If membrane potential is less negative than -65mV, GABA mediates hyperpolarizing IPSP
- Two Mechanisms
  - Hyperpolarization
  - Shunting Inhibition: Inhibiting current flow from dendrites and soma to axon hillock

The IPSPs reduce the size of EPSPs, making the postsynaptic neuron less likely to fire action potentials.

# Synaptic Modulation

- Synaptic transmission that modifies effectiveness of EPSPs generated by other synapses

- Activating NE β-receptors
  - Close $K^+$ Channels
  - Decreasing the $K^+$ conductance increases the dendritic membrane resistance and therefore increases the length constant
  - Distant or weak excitatory synapses will become more effective in depolarizing the spike-initiation zone beyond threshold; the cell will become more excitable

# References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