Transformation of Synaptic Input into Action Potential

Most of the signals transmitted among neurons are in the form of action potentials (all-or-nothing membrane potential changes, spikes). They propagate without decrement along a neuron's axon to it synaptic terminals, where transmission to another cell occurs. Each neuron must transform the graded synaptic response input into physiologically meaningful patterns of action potentials for propagation down its axon. This encoding occurs in:

- In the cell body.
- In dendrites.
- The proximal axon of the neuron.

It requires voltage-gated ionic channels. The density and type of ionic channels in the cell membrane varies within the dendritic, somatic and axonal membranes. It underlies the functional properties of the individual segments of the neuronal membrane:

- Myelinated axon: Na^+-VGCs are responsible for the profound depolarization during action potential and they are restricted to the nodal region.
- Dendritic and somatic membranes (post-synaptic regions): ligand-gated channels.

Summation

Action potentials are normally initiated at a low threshold "trigger zone" that is more excitable than any other part of the soma or dendrites. This trigger zone is located at the axon initial segment, the **axon hillock** (which contains the highest density of Na^+-VGCs). Synaptic input located close to the trigger zone is more effective in depolarizing and hyperpolarizing it than synaptic inputs of equal strength located further away. If depolarizing synaptic current is large enough, it brings the membrane potential of the initial segment to threshold ⇒ an action potential is initiated and propagates down the axon. If the local conditions are favorable, it may propagate also backward into the soma/dendrite region.

Since the trigger zone is located distant from most synaptic inputs, it acts as averaging site where the synaptic currents flowing from the entire dendritic tree and the soma are summed, thus making it the site where the decision is made to send a spike down the axon or not. Unlike the spike in an axon, the spike recorded in the soma of a neuron is not a unitary event. It represents activation of spatially distinct regions of the neuron.

Composition of the Spike of Action Potential

The spike recorded in the soma is usually composed of an A and B components:

- The A spike is also called the IS spike, because the A region is the axon initial segment. It temporally coincides with the onset of the action potential propagating along the axon. A certain level of hyperpolarization can depress the A spike.
- The B spike (the SD spike) is generated in the soma/dendritic region. It does not propagate down the axon, but only activates many voltage-sensitive conductances in the soma/dendritic region, (e.g.: K^+ conductance ⇒ long-lasting after-hyperpolarization (AHP)). The B spike has longer refractory period, therefore during higher frequency antidromic stimulation it disappears. Besides the soma, the B component occurs also in the proximal segments of the dendrites.

Links

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- Inhibitory Neuronal Circuits
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- Synapse
- Neuromuscular Transmission
- Membrane Potentials
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Sources

- Lecture Notes: Prof. MUDr. Jaroslav Pokorný DrSc.

Bibliography

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Further reading