II. Model Neuron

Reading: W.J. Freeman, Mass Action in the Nervous System, chapter 1.

Model Neuron Components

We want to simplify the diversity of neuronal form by formulating a model neuron having essential operations.
Neural activity occurs in two modes: wave and pulse.
Operation: Transmission of neural activity from one part of a neuron to another, or from one neuron to another; or transformation of neural activity by a neuron or part of a neuron.

The simplified model neuron has 4 operations

(1) Wave propagation in the dendrite

Dendrite generates ionic currents that continuously vary in amplitude.
These currents generate potential differences across the membrane -- activity in the wave mode.
The function of the dendrite is integration of its ionic currents in space and time.

(2) Pulse transmission in the axon

Axon generates trains of pulses -- activity in the pulse mode.
The function of the axon is transmission of activity from one location to another with delay;
amplification is in proportion to the number of axon terminals.

(3) Wave-to-pulse conversion at the trigger zone

The initial segment of the axon is the site where the sum of dendritic currents determines the pulse frequency of the axon.
The function of the trigger zone is the instantaneous conversion of wave amplitude to pulse frequency.
If the neuron is given a steady suprathreshold depolarizing bias, the neuron generates a pulse train at some mean pulse rate.

(4) Pulse-to-wave conversion at the synapse

The synapse -- site of conversion of 1 neuron's pulse activity to wave activity of another neuron. The transmitter released by the presynaptic axon terminal crosses the synaptic cleft by diffusion. In causing ion channels to open, it effectively activates electromotive forces in the postsynaptic neuron. These emf's drive the dendritic current in the postsynaptic neuron.

If a pulse is delivered to a neuron at rest by way of the axons ending on its dendrites and soma, a brief wave of dendritic potential occurs, which is a postsynaptic potential (PSP).

If an input axon bundle is stimulated, the response is a compound PSP.

There are two fundamental classes of neurons in terms of the nature or "sign" of their effects on other neurons.

Synaptic inputs that depolarize a neuron and increase its pulse rate or pulse probability are called excitatory, and the postsynaptic potential is an EPSP.

Synaptic inputs that hyperpolarize a neuron and decrease its pulse rate or pulse probability are called inhibitory, and the postsynaptic potential is an IPSP.

The sign of action is independent of the active state of the neuron, i.e. the level of activity does not determine whether the neuron is excitatory or inhibitory.