Point Neurons and Compartment Models

Synaptic Interaction

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1. Cell Shapes
   - Point Neurons
   - Compartments
   - Axon Modeling

2. Synapses
   - Post-Synaptic Potentials
   - Modeling Synapses

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So far, we have ignored the shape of the neuron
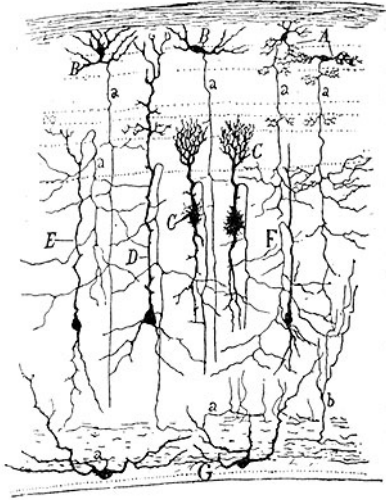
Point Neuron

- Neuron model where shape (morphology) is ignored
- Same potential everywhere inside
- All currents go into the same pool

Is this an acceptable approximation?

Typical neurons

- Thin branches
- Too fast events for the potential to reach a steady state
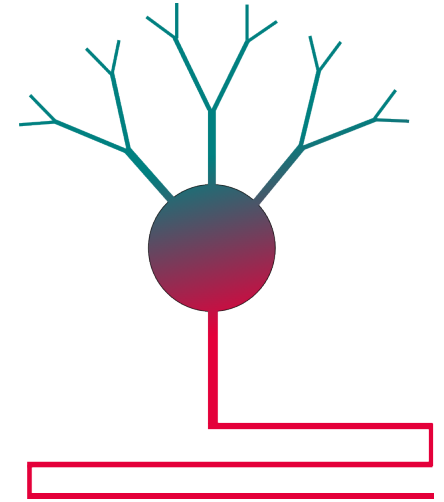- Non-uniform distribution of ion channels

Still — The point neuron approximation is often "good enough"

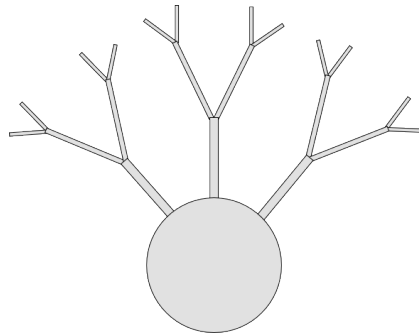---

Main parts of a neuron

What happens where?

- Dendrites
  Collect input
- Soma
  Regular cellular machinery
- Axon
  Distributes output

Modeling dendritic trees

- Compartment Models
- Each compartment has its own potential
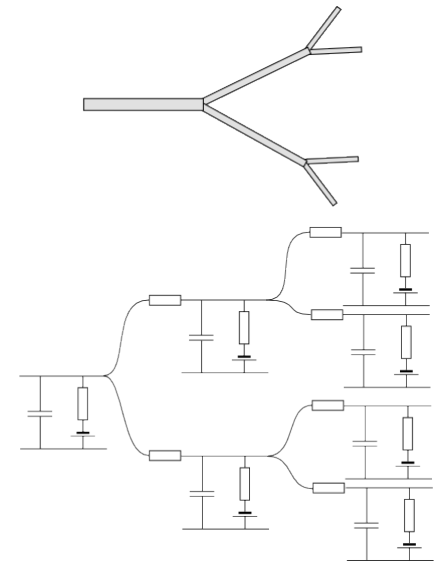- Conductance between compartments
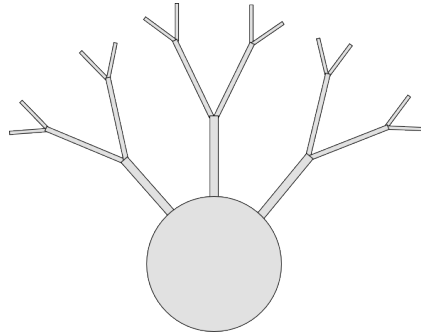

Compartment Models

Each compartment has its own:

- Potential
- Membrane Capacitance
- Leak Conductance and Reversal Potential

Core conductance between compartments

Cell Shapes   Point Neurons
Synapses   **Compartments**
Axon Modeling

Possible computational
consequences

- Inputs far out have less
  influence on spike generation
- Local interaction between
  incoming signals
- Shunting inhibition

Cell Shapes   Point Neurons
Synapses   Compartments
Axon Modeling

Axon

- Propagating action potential
- Pure delay
- Myelin accelerates
- Possible implementation:
  Delay queue
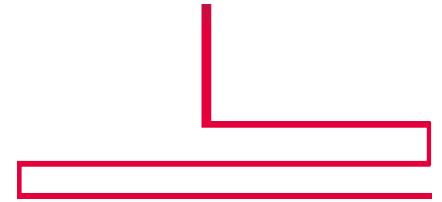
Action Potential $\Rightarrow$
Transmitter Release

Binding to Receptors $\Rightarrow$
Ion Channels open

Post-Synaptic Potential (PSP)

- Excitatory PSP (EPSP)
  Increases potential
  Unspecific ion channels
- Inhibitory PSP (IPSP)
  Decreases potential
  Chloride channels
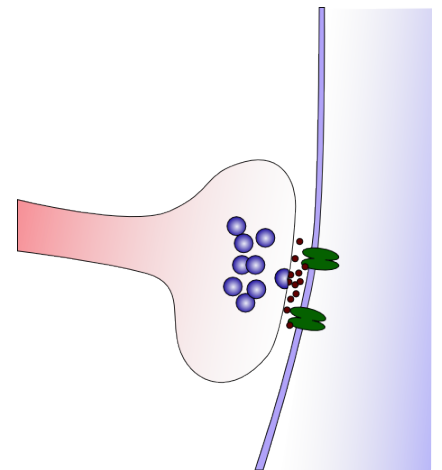
- Common synapse model
  Conductance changes
  according to *Alpha function*

$$t \cdot e^{-t}$$

- Alternatives
  - Current injection
  - Instantaneous current
    injection

Conductance

Time

Spike arrives