the knee-jerk reflex – a neuro “system”

principles: ‘the neuron doctrine’ & ‘the law of dynamic polarization’
systems neuroscience = structure \hspace{1cm} dynamics

structure:
(micro) synapses $\rightarrow$ neurons $\rightarrow$ nuclei $\rightarrow$ regions (macro)

dynamics:
synaptic & action potentials (micro) $\rightarrow$ field potentials / EEG $\rightarrow$ fMRI (macro)
neurons come in variety of shapes and sizes
Cajal’s ‘neuron doctrine’: the neuron as the basic structural and functional unit of the brain

Cajal’s ‘law of dynamic polarization’: neural / electrical transmission proceeds in one direction -
dendrite / soma → axon → axon terminal
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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</thead>
<tbody>
<tr>
<td>membrane potential</td>
<td>the voltage difference between the intracellular space of a neuron and the surrounding extracellular space (includes resting, synaptic, and action potentials)</td>
</tr>
<tr>
<td>synaptic potentials</td>
<td>excitatory and inhibitory inputs from one neuron (at its axon terminal) onto another (at its dendrite or soma)</td>
</tr>
<tr>
<td>action potentials</td>
<td>all-or-none electrical events in a neuron which reflect the spatial and temporal integration of synaptic potentials and the intrinsic excitability of the neuron</td>
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<tr>
<td>equilibrium potentials</td>
<td>the membrane potential at which the net flux of ions across the membrane is 0 given the overall concentrations of that ion on either side of the membrane</td>
</tr>
</tbody>
</table>
recording membrane potentials
electrical potentials reflect the dynamics of ion concentrations at the membrane surfaces
properties of ion channels:

* ion selectivity – e.g., Na+, Ca++, K+, Cl-
* gating – e.g., by voltage, ligand
* kinetics – e.g., open-time
* state – e.g., activated, inactivated, deinactivated, persistent
* distribution – e.g., in dendrites, at axon hillock
The Nernst Equation

- used to determine the equilibrium potential
- relates ion concentration gradients to electrical charge gradients (i.e., defines how they balance each other out)

\[ E_{\text{ion}} = \frac{RT}{zF} \ln\left(\frac{[\text{ion}]_o}{[\text{ion}]_i}\right) \]

(R = gas constant  T = temp.  z = valence (+1, -1)  F = Faraday’s constant)

E = membrane potential at which net ion flux is 0 (equilibrium) given specific intracellular and extracellular concentrations of ions.

Nernst values for different ions (in mammalian neurons)

<table>
<thead>
<tr>
<th></th>
<th>[ion]_i (mM)</th>
<th>[ion]_o (mM)</th>
<th>E_ion (mV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K+</td>
<td>135</td>
<td>3</td>
<td>-102</td>
</tr>
<tr>
<td>Na+</td>
<td>18</td>
<td>150</td>
<td>+56</td>
</tr>
<tr>
<td>Cl-</td>
<td>7</td>
<td>120</td>
<td>-76</td>
</tr>
<tr>
<td>Ca++</td>
<td>0.1 μM</td>
<td>1.2</td>
<td>+125</td>
</tr>
</tbody>
</table>
action potentials

**Graph 1:**
- **Y-axis:** Membrane potential (mV)
- **X-axis:** Time (ms)
- **Graph:**
  - Action potential

**Graph 2:**
- **Y-axis:** Conductance (mSiemens/cm²)
- **X-axis:** Time (ms)
- **Graph:**
  - Na⁺
  - K⁺
action potentials: reflect dynamics of Na+ and K+ ion movements across the membrane
action potential conduction speed is a function of axon length and myelination (or lack thereof)
synaptic potentials
neurotransmitters: mediating information exchange between neurons through generation of synaptic potentials

three basic types of neurotransmitter:
1. excitatory (glutamate, ACh)
2. inhibitory (GABA, glycine)
3. neuromodulatory (NE, 5-HT, DA, HA, Ach)
synaptic integration
synaptic integration: temporal vs. spatial