Neuronal Signalling

Generation of the Resting Membrane Potential

Lipid bilayer insulates inside of cell from extracellular space
Channels and pumps work together to create and maintain membrane potential
Diffusion is chemical driving force
Selective permeability to ion species creates a competition between electrical and diffusion forces
Gibbs-Donnan equilibrium describes the equilibrium between electrical and chemical forces
Selective permeability to K+ leads to resting membrane potential in cells, including neurons
Nernst equation uses the ion concentration of a single ion species at equilibrium to describe the resting membrane potential
Resting membrane potential is approx -70mV (inside relative to outside)
Na+/K+ pumps maintains the membrane voltage against ion leakage
The Goldman equation uses the ion concentration of multiple ion species at equilibrium to describe the resting membrane potential – the contribution of each is weighted by the permeability of the membrane to that ion species (more permeability = more weight)
Depolarization refers to an increase in membrane potential (toward zero)
Hyperpolarization refers to a decrease in membrane potential (away from zero)

Passive Electrotonic Conduction

Unequal distribution of ions acts as a battery
The membrane resistance (Rm) is determined by ion channels
The cell membrane can be charged (with ions) and discharged similar to a capacitor
The axial resistance Ri is determined by the diameter of the dendrite
The length constant (lambda) describes how far a signal will travel down a dendrite before voltage drops to 1/3 of the original voltage
Know why:
Small Rm -> small lambda
Large Rm -> large lambda
Small Ri -> large lambda
Large Ri -> small lambda
Small Lambda -> less spatial summation
Large Lambda -> more spatial summation
The time constant (tau) describes how fast a signal will dissipate to 1/3 the max voltage
Small Rm -> small tau
Large Rm -> large tau
Small Tau -> less temporal summation
Large Tau -> more temporal summation

Active (Regenerative) Conduction

Active conduction permits propagation of signals over long distances
Axons utilize active conduction
A neuron will fire an action potential if the membrane potential reaches threshold
Action potential firing is caused by Na+ channel opening
Action potential firing is “all or none” because ion channel opening increases voltage, which causes more ion channels to open
The action potential is terminated by deactivating of Na+ channels and opening of K+ channels
Inactivation of Na+ channels leads to an absolute refractory period (the cell cannot fire)

Open K+ channels and residual Na+ channel inactivation leads to a relative refractory period (stronger input needed to fire)
Myelin increases lambda and decreases tau by decreasing Rm and decreasing Cm
Saltatory conduction allows for fewer time consuming regenerations of the signal