Propagation of action potentials

*How is AP generated?* - integration signal, threshold, voltage gated Na\(^+\) and K\(^+\) channels

*How does AP propagate?*

**Local potentials** play a key role in AP propagation.
Subthreshold membrane potential graded signal (decay with distance)

Local potential and passive electrical properties of the membrane
Membrane resistance - Resistive current
Membrane capacitance - capacitative current
A patch of membrane is electrically equivalent to an RC circuit
Current injection
Time dependent voltage change
Initial change - capacitative
steady-state - resistive

FIGURE 11. The equivalent resistance and capacitance of a cell membrane can be measured by noting its response to rectangular pulses of current. (A) Two glass
Velocity of AP propagation is determined by length constant lambda ($\lambda$):

Larger $\lambda \Rightarrow$ Faster propagation: Myelination and thicker axon

FIGURE 12. Local potentials in cylindrical structures (cables) decay as a function of distance from the site of origin. (A) A portion of a long cable is shown with a
Propagation of Action Potentials

Passive currents flowing from depolarized region (where AP is occurring) to the nearby regions proceed the propagation of AP.
Action Potentials and information

1. Generation of AP is All-or-None
   Small fluctuations of the membrane potential can not be misinterpreted by the neuron.

2. Amplitude of AP is independent of the size of the stimulus.
   Amplitude of response do not reflect the amplitude of stimulus.

3. Larger stimulus $\Rightarrow$ Shorter latency

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Figure 3-5. Active responses to large depolarizing stimuli. Although small depolarizing responses produce a passive membrane response, as in Figure 3-3, the voltage response to larger depolarizing currents is very different.
Refractory period and stimulus intensity determine the frequency.

Absolute refractory period

Relative refractory period

Figure 3-6. The threshold is not fixed. For a short period of time after the firing of an action potential, the threshold is much greater than normal.

Frequency coding in axons

Figure 3-7. Frequency coding in axons. a: An above-threshold sustained depolarizing stimulus (I) produces action potentials at a certain frequency. b: When the depolarizing stimulus is larger, the frequency of action potential firing is greater.
Input signal-Graded local signal
Receptor potential- sensory neurons
Synaptic potential- interneurons and motor neurons
Endplate potential- muscle

Endplate potential (epp)
Acetylcholine (ACh) released from a motor neuron activates a muscle fiber through ACh receptor (AChR).
This AChR-nicotinic acetylcholine receptor a ligand gated ion channel permeates Na⁺ and K⁺

At normal resting potential, ACh produces inward current.

FIGURE 16. The endplate potential (epp) is generated by a brief surge of current, the endplate current. The currents that underlie the epp, which can be recorded by voltage clamp (lower trace), are considerably briefer than the potential change they produce (upper trace). Much of the falling phase of the epp occurs after the endplate current has returned to baseline. The time course of this part of the epp is determined by the passive electrical properties of the myofiber.
Reversal potential
* at which the change of the direction of current occurs.
* Na⁺ current becomes equal to K⁺ current in this case.
Analysis of epp revealed the nature of synaptic transmission.

1. Quantal release of neurotransmitters

2. Statistical fluctuation of the synaptic potential probability events

Poisson equation

$$P_x = \frac{m^x}{x!} e^{-m}$$

$P_x$: probability of epp containing $x$ quanta

$$m = \frac{\text{mean amplitude of epp}}{\text{mean amplitude of mepp}}$$

**FIGURE 18.** Transmitter is released in multimolecular packets called quanta.