NEURONS
Chapter 11

Figure 11.1 Neuronal and hormonal signaling both convey information over long distances

1. Nervous system
   A. nervous tissue
   B. conducts electrical impulses
   C. rapid communication
2. Endocrine system
   A. various tissue types
   B. chemical messengers
   C. slow speed of action, broadcast

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Nervous Systems

1. Neurons are specialized cells of the nervous system
   A. Nerves are bundles of neuron axons
2. Neurons with their support cells (glial cells) make up nervous systems.

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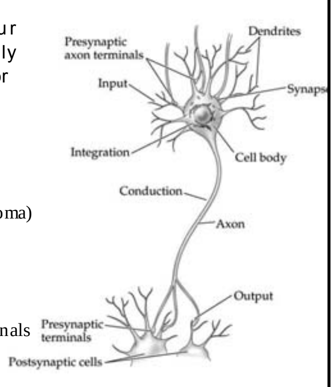
Figure 11.2 Neurons have four functional regions that typically correspond to their four major structural regions

1. Dendrites
   A.
2. Neuronal cell body (Soma)
   A.
   B. axon hillock
3. Axon
   A.
4. Presynaptic axon terminals
   A.



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Vertebrate Nervous Systems

1. Receptors
2. Peripheral nervous system (PNS)
   A. sensory and motor neurons
3. Central nervous system (CNS)
   A. brain and spinal cord
4. Effector cells
   A. muscle or gland cells
   B. cause behavioral or physiological responses

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Simple Nerve Circuit

1. Sensory neurons: convey information (afferent) from a sensory receptor to spinal cord
2. Interneurons: information integration by CNS
3. Motor neurons: convey signals (efferent) to effector cell (muscle or gland)
4. Reflex: simple response; sensory to motor neurons

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Figure 11.5 Glial cells

1. Supporting or Accessory Cells in Nervous System
   A. outnumber neurons 10:1 in human brain
   B. provide neurons with nutrients,
   C. remove waste products & maintain ionic environment
   D. Form myelin sheaths

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HOW NERVE CELLS FUNCTION

1. Excitable cells
   A. cells that can change membrane potentials
2. Resting potential
   A. the unexcited state
   B. voltage differences across the plasma membrane
   C. Membrane potentials were first demonstrated using the giant axons of a squid (1mm diameter).

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Figure 11.7 Recording the resting membrane potential of a squid giant axon

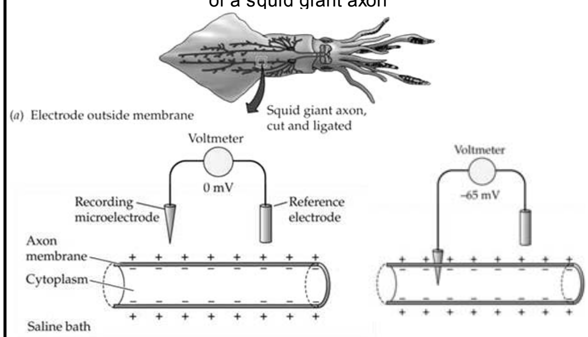

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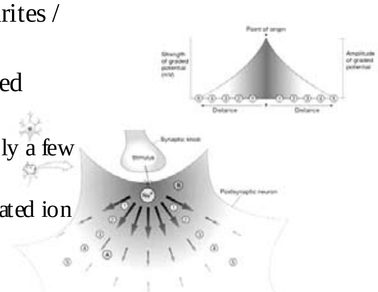
Figure 11.9 Graded potentials decrease exponentially with distance

1. occur in dendrites / cell body
2. small, localized change
   A. change of only a few mV
   B. opening of gated ion channels



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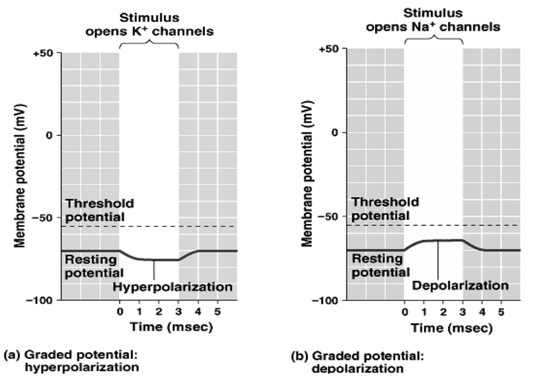
Graded Potentials



1. Figure 11.10 Selective permeability of a membrane gives rise to a membrane potential
2. Figure 11.11 The membrane potential results from relatively few charges sitting on the membrane

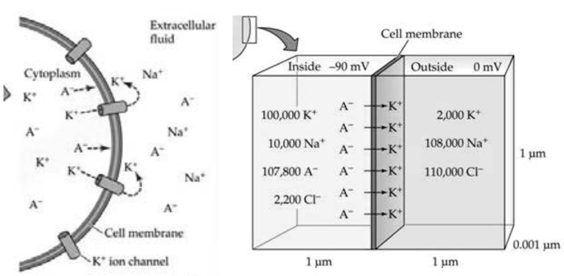
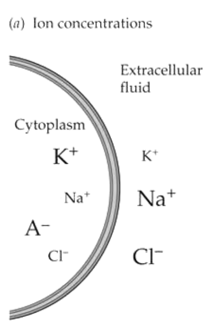


Figure 11.12a Concentration of major ions in intracellular and extracellular fluids (Part 1)

1. Cells have
   - A. low Na and Cl,
   - B. high K and non-permeating anions (A)
2. Symbol sizes represent relative concentrations



The Nernst Equation

$$E_{ion} = \frac{61}{z} \log \frac{[ion]_{out}}{[ion]_{in}}$$

Goldman Equation

$$V_m = 60 \log \frac{P_K[K^+]_{out} + P_{Na}[Na^+]_{out} + P_{Cl}[Cl^-]_{in}}{P_K[K^+]_{in} + P_{Na}[Na^+]_{in} + P_{Cl}[Cl^-]_{out}}$$

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Membrane Proteins Involved in Electrical Signals

1. Non-gated ion channels (leak channels)
   A.
   B.
2. Gated Ion channels
3. Ion pumps

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Gated ion channels

1. open/close in response to particular stimuli
   A. Light (photoreceptors)
   B. vibrations in air (sound receptors)
   C. chemical (neurotransmitters)
   D. voltage (membrane potential changes)
      a. are all-or-none channels
      b. close soon after opening
      c. potassium and sodium pass through different channels

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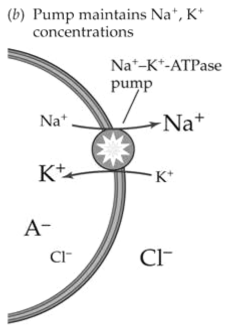
Fig 11.12b **Ion pumps** help maintain the concentration of major ions in intracellular and extracellular fluids

1. Active transport Na-K pumps
2. Counteract the tendency of Na to diffuse in and K to diffuse out.



The sodium and potassium gradients for a resting membrane

1. Sodium-Potassium Pump
   A. Three Na^+ OUT for every two K^+ IN
   B. energy supplied by ATP
   C. thousands of pumps per square micron
2. Protein and chloride ions carry negative charges inside the cell.
3. At rest, few Na ions cross the membrane except by the Na-K pump.
4. K flows into the cell because of the electrical gradient and flows out because of the concentration gradient.

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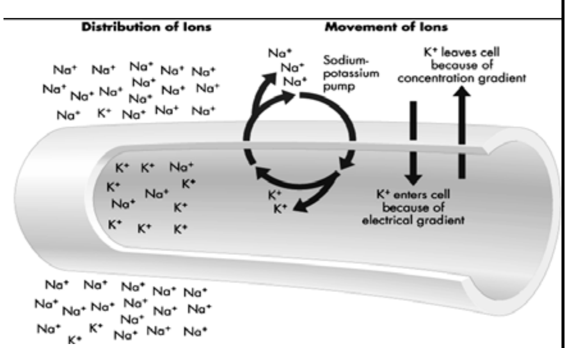
The sodium and potassium gradients for a resting membrane



Summing up the resting potential

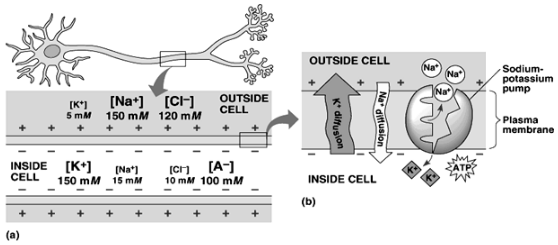


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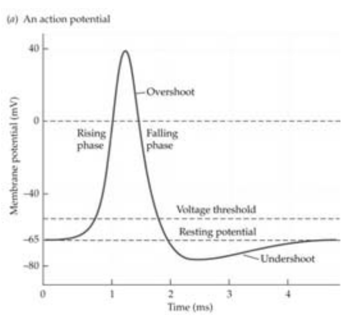
Fig 11.14 General features of action potentials



Three phases

A. Depolarization
B. Repolarization,
C. Hyperpolarization

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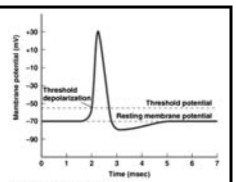
Action Potentials



1. Triggered at the ***axon hillock***
2. If stimulus reaches ***threshold potential*** (−50 to −55 mV), Na channels open
3. All or nothing response, Does not degrade
4. Travels long distances

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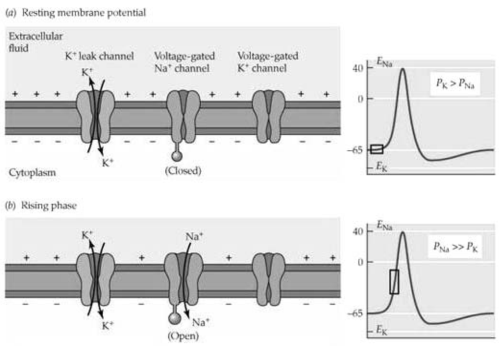
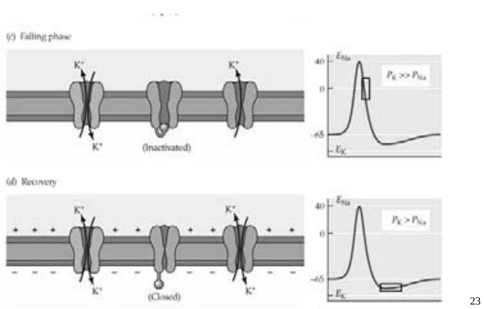
Figure 11.15 Membrane permeability changes that produce an action potential





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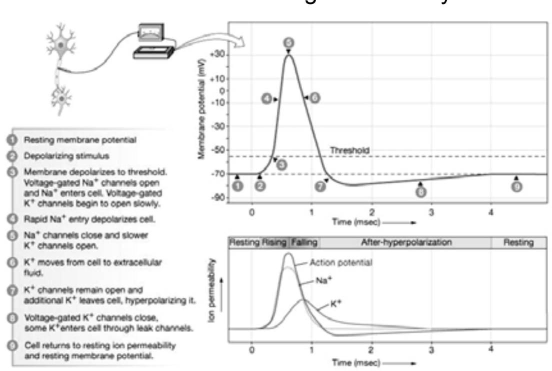
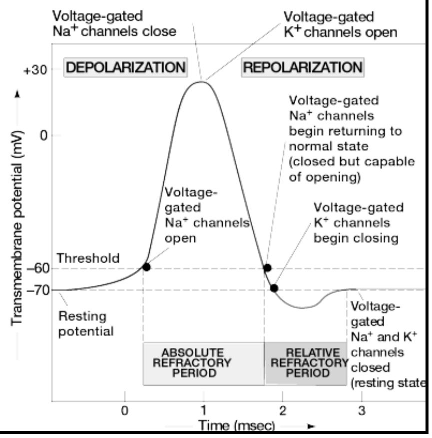
Action Potential Stages: Summary



Refractory periods

1. Absolute Refractory Period
2. Relative Refractory Period



Nerve Impulses

1. Action potential: all-or-none response
   A. size, amplitude, and velocity are independent of the intensity of the stimulus that initiated it
2. More intense stimulus causes more FREQUENT firing
3. signal does not weaken (conduction-without-decrement).
4. Travel is self-propagating
5. depolarization sends a wave of depolarization down the axon due to the voltage-gate channels
6. Forward direction only
7. Regeneration of "new" action potentials only after refractory period

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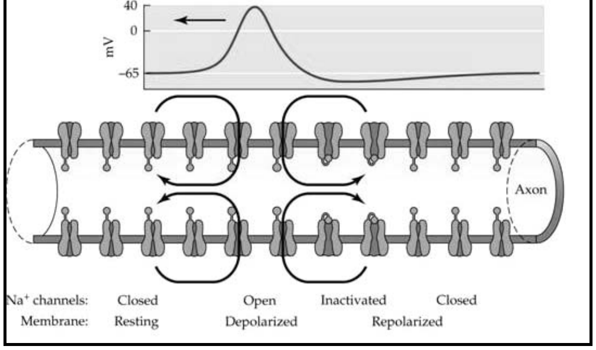
Fig 11.26 Inactivation of voltage-gated Na+ channels prevents reverse propagation of an action potential



Conduction of action potentials 3

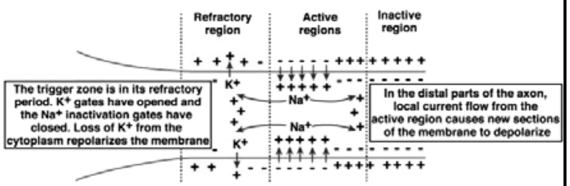


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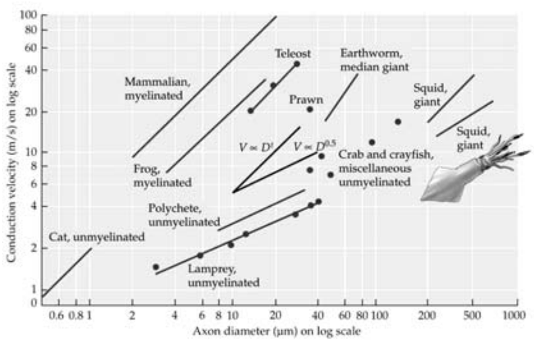
Figure 11.27 The velocity of nerve-impulse conduction



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1. AP Velocity is
   A. proportional to diameter in myelinated axons
   B. proportional to the square root of the axon diameter in unmyelinated axons
2. FASTER transmission
   A. Resistance to electrical current inversely proportional to cross-sectional area
   B. Increased diameter lowers internal resistance
   C. In thick axons, depolarization in one location 'reaches' further up axon than in thin axons.

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Conduction Velocity in Invertebrates

1. Thin axons:
   A. V = 100cm/second (sea anemones)
2. Thick axons (1 mm):
   A. about 100 times thicker than vertebrate nerves
   B. V = 100m/second (squids/lobsters)

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Vertebrate Myelinated Fibers

1. Schwann cells
   A. wrap around vertebrate axons
2. myelin
   A. lipid insulator in membranes
3. Nodes of Ranvier
   A. uncovered areas at regular intervals of the axon
   B. contain Na+ channels

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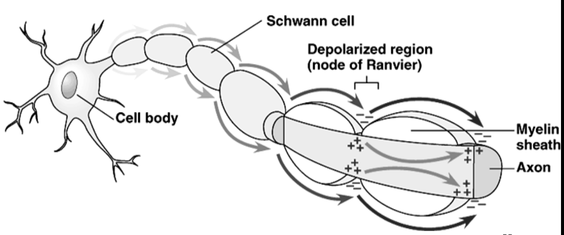
Saltatory conduction

1. signals "jump" from one node to the next
   A. Increase AP conduction speed 50-100x
   B. Conduction to 150m/seconds



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Speed of Conduction

1. myelination allows nerve fibers to be much thinner.
2. our optic nerve would be 25 cm in diameter, instead of 3 mm.
3. For very small fibers (less than 1 micron), unmyelinated conduct faster

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Figure 8-16b: Axon diameter and speed of conduction

How does myelination work ?

1. Ion channels are concentrated in Nodes of Ranvier
2. Extracellular fluid in contact with axon only at gap
3. Flow of ions only occurs at nodes/gaps
4. Action Potential (depolarization) jumps from node to node and skips insulated region

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