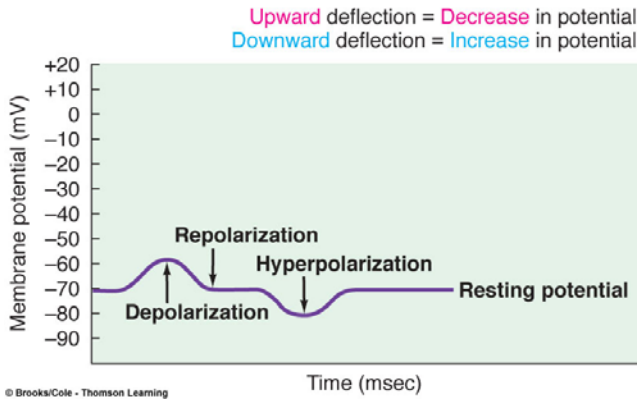
Νευροφυσιολογία και Αισθήσεις

Διάλεξη 4

Δυναμικά Ενεργείας (Action Potentials)

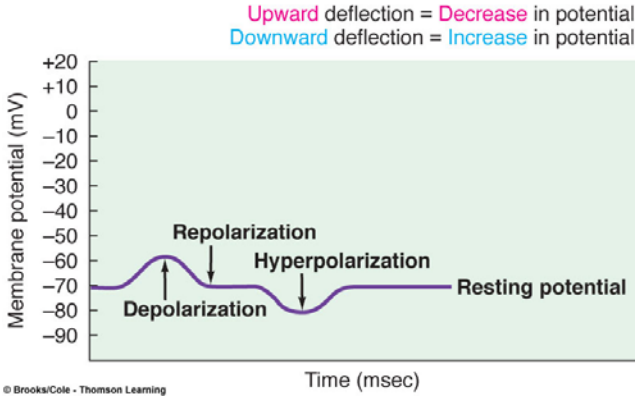
Excitable Tissues

- **Nerve and muscle are excitable tissue**
  - Change their membrane potential to produce electrical signals
  - Neurons → messages
  - Muscle → contraction
- **Membrane potential changes**
  - Polarization
    - When a potential (either + or -) exists across a membrane
  - Depolarization
    - Reduction of the magnitude of potential (e.g. -70 mV → -50 mV)
  - Repolarization
    - Return to resting potential
  - Hyperpolarization
    - Increase in the magnitude of the potential (e.g. -70 mV → -90 mV)



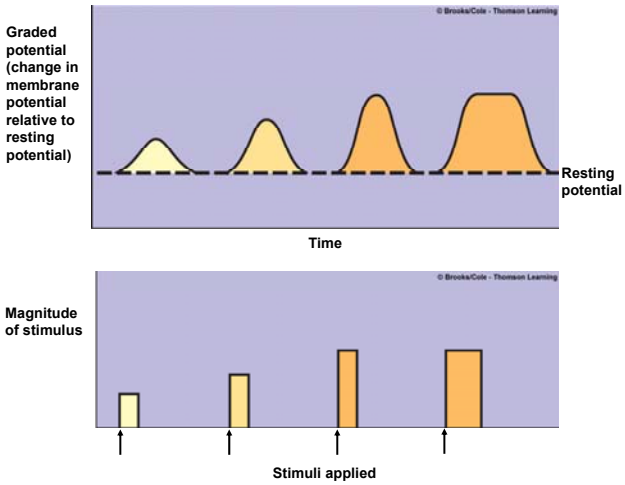
Excitable Tissues

- **Changes are triggered by**
  - Change of the local electrical field
  - Interaction with chemical messenger and surface receptor
  - Stimulus (e.g. sound, light, etc)
  - Spontaneous change of potential by inherent ion leaks
- **Changes are caused by movement of ions**
  - Leak channels
    - Open all the time
  - Gated channels
    - Can be open or closed (conformation change)
    - Types
      - Voltage gated
      - Chemically gated
      - Mechanically gated
      - Thermally gated
- **Electrical signals**
  - Graded Potentials
  - Action Potentials



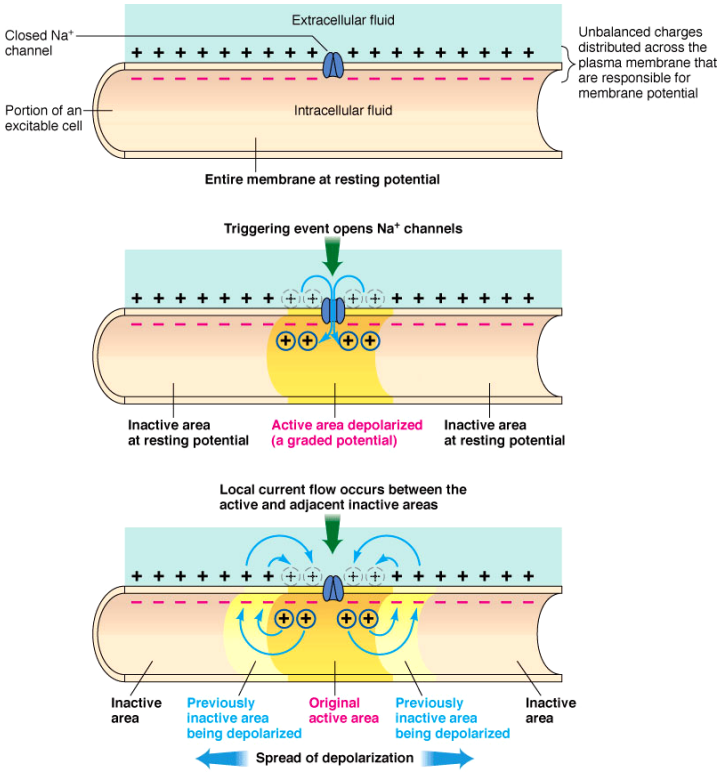
Graded Potentials

- **Local changes in membrane potential**
  - Confined to small area, the ***Active Area***
  - Remaining cell is still at resting potential, the ***Inactive Area***
  - Triggered by specific events
  - Gated channels (usually Na+ open)
  - Magnitude and duration proportional to triggering event



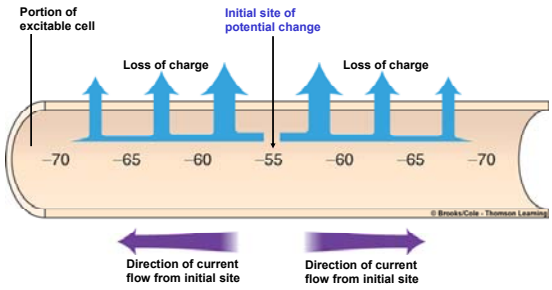
Graded Potentials

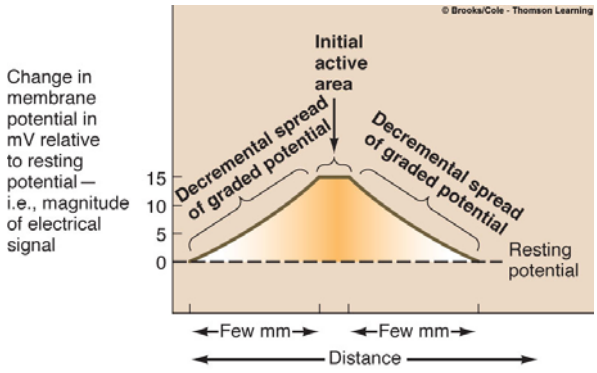
- **Propagate to adjacent areas**
  - Movement of ions = current
  - Current spreads in the ECF and ICF (low resistance) but not through the membrane (high resistance)
  - Depolarizes adjacent regions
  - Graded potentials propagate



Graded Potentials

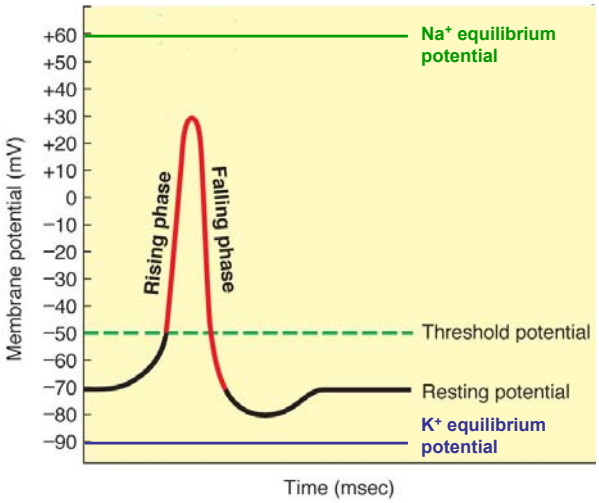
- **Graded potentials die out over short distances**
  - Loss of charge
  - Magnitude decreases as it moves away from the point of origin
  - Completely disappear with a few mm
- **Grades potentials are important**
  - Postsynaptic potentials
  - Receptor potentials
  - End-plate potentials
  - Pacemaker potentials
  - Slow-wave potentials





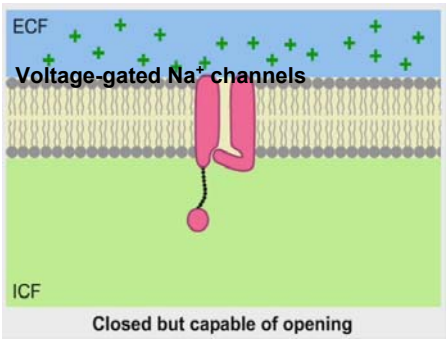
Action Potentials

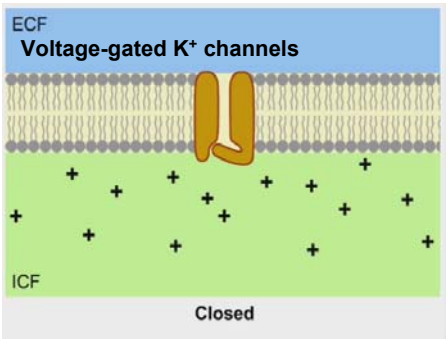
- **Large (~100 mV) changes in the membrane potential**
  - A.k.a *spikes*
  - Can be initiated by graded potentials
  - Unlike graded potentials action potentials propagate
  - Transmit information
- **Changes during an action potential**
  - Gradual depolarization to threshold potential (-50 to -55 mV)
    - If not reached no action potential will occur
  - Rapid depolarization (+30 mV)
    - Portion between 0 and 30 mV is called an *overshoot*
  - Rapid repolarization leading to hyperpolarization (-80 mV)
  - Resting potential restored (-70 mV)
- **Constant duration for given cell type**
  - E.g. Nerves → 1 msec



Action Potentials

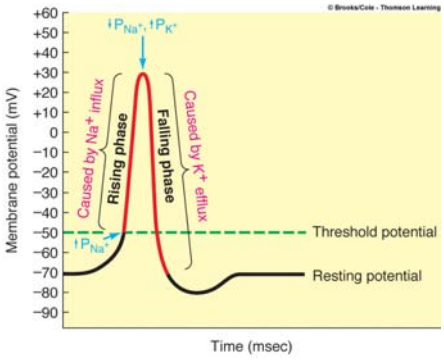
- **AP are a result of changes in ion permeability**
  - Voltage-gated channels
    - Proteins which change conformation depending on potential
    - Allow passage of ions
    - Voltage-gated Na^+ channels
      - Activation (immediate) and inactivation gates (delayed)
    - Voltage-gated K^+ channels
      - Activation gate (delayed)

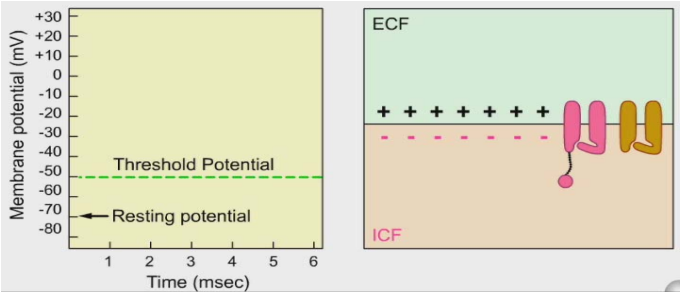




Action Potentials

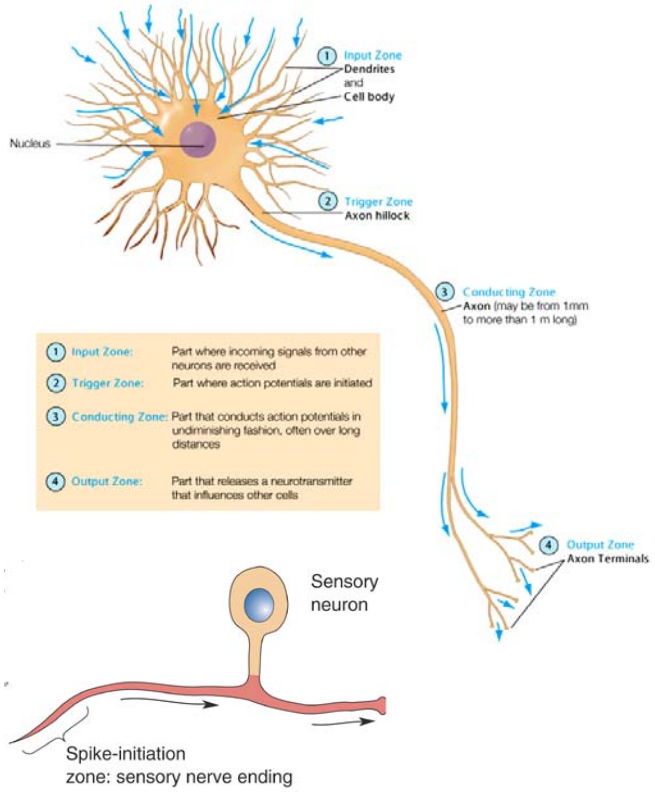
Time	Event	Potential
0 msec	Resting state All channels are closed Graded potential arrives Begins depolarization	- 70 mV
0.3 msec	Threshold reached Activation gates of Na+ channels open Activation gates of K+ channels begin to open slowly Inactivation gates of Na+ channels begin to close slowly	- 50 mV
0.5 msec	Peak potential reached Inactivation gates of Na+ channels are now closed Activation gates of K+ channels are now open	30 mV
0.8 msec	Hyperpolarized state Activation gates of K+ channels close	- 80 mV
1 msec	Resting state Na+-K+-pump restores resting potential Na+ channels are reset to close but active	-70 mV





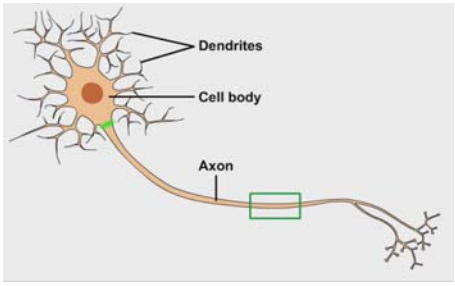
Action Potentials

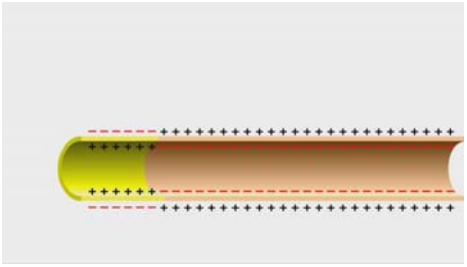
- **Neuron structure**
  - Input Zone
    - Dendrites (up to 400 000)
    - Cell Body
    - Have receptors which receive chemical signals
  - Conduction zone
    - Axon or nerve fiber (axon hillock to axon terminals) <1 mm to >1m
  - Output zone
    - Axon terminal
- **Input**
  - Synapse
    - Graded Potentials
    - Generated in the dendrites as a response to chemical signals
    - Can trigger action potentials in the axon
  - Sensory nerve endings



Action Potentials

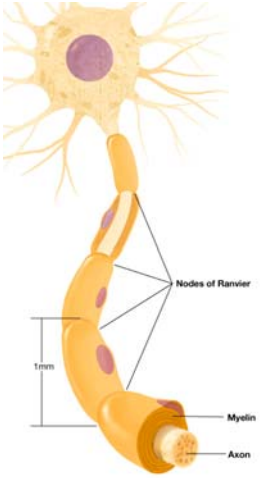
- **AP Propagation**
  - APs initiated at the axon hilloc
    - More voltage-gated channels → lower threshold
  - Once initiated the AP travels the entire axon
    - Contiguous conduction
    - Saltatory conduction
- **Contiguous conduction**
  - Flow of ions → depolarization of adjacent area to threshold
  - As AP is initiated in adjacent area, the original AP is ending with repolarization
  - The AP itself does not travel, it is regenerated at successive locations (like "wave" in a stadium)

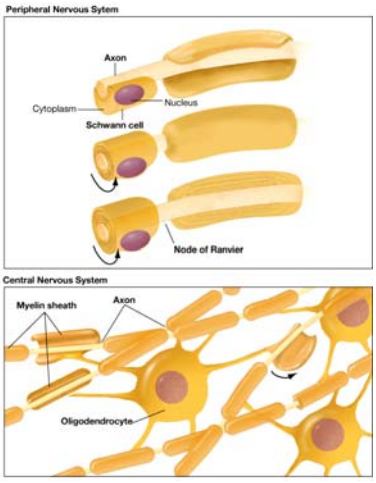




Action Potentials

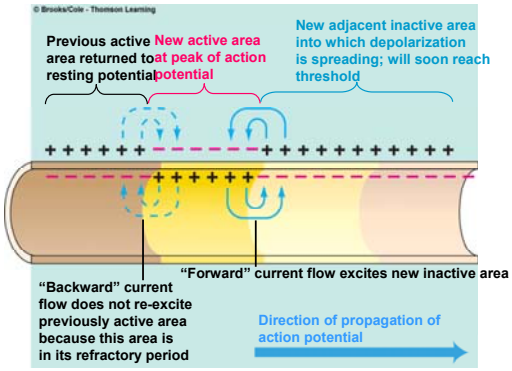
- **Saltatory Propagation**
  - Some neurons are myelinated
    - Covered with myelin (lipid barrier)
    - Formed by oligodendrocytes (CNS) and Schwann cells (PNS)
    - No ion movement across myelinated areas
  - Nodes of Ranvier
    - Areas between myelin sheaths
    - Ions can flow → APs can form
  - Local current can generate AP at the next node
  - APs "jump" from node to node → information travels 50x faster, less work by pumps to maintain ion balance
  - Loss of myelin can cause serious problems
    - E.g. multiple sclerosis

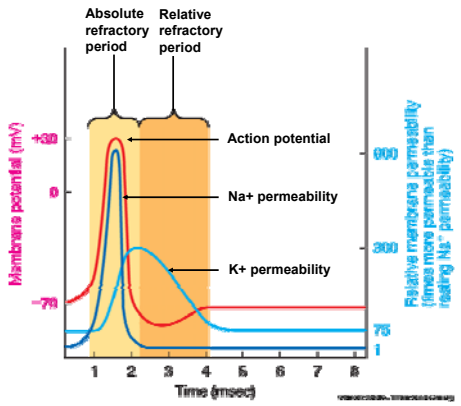




Action Potentials

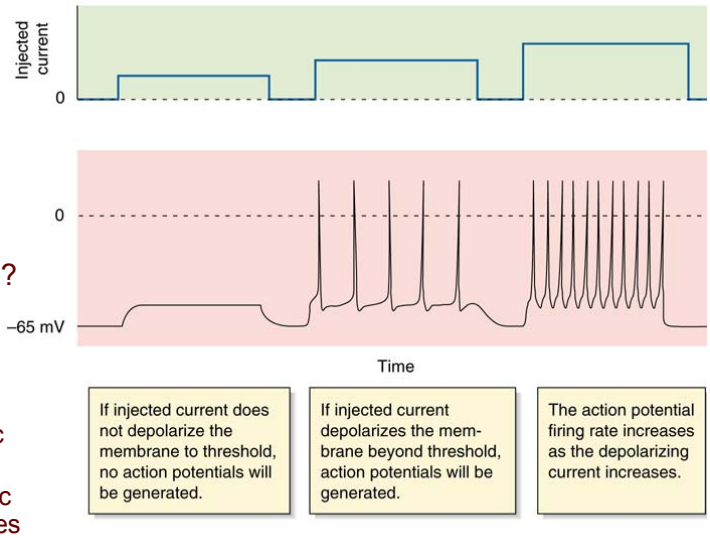
- **Refractory Period**
  - APs do not travel backwards
    - Local currents do not regenerate an AP in the previously-active-now-inactive area
  - Certain time must pass before a second AP can be triggered → ***refractory period***
  - Absolute refractory period
    - During an AP
    - No APs can be triggered
  - Relative refractory period
    - Na^+ channels are mostly inactive
    - K^+ channels are slow to close
    - After an AP → second AP can be triggered only be exceedingly strong signals
  - Refractory period sets an upper limit to the frequency of APs →~2.5 KHz





Action Potentials

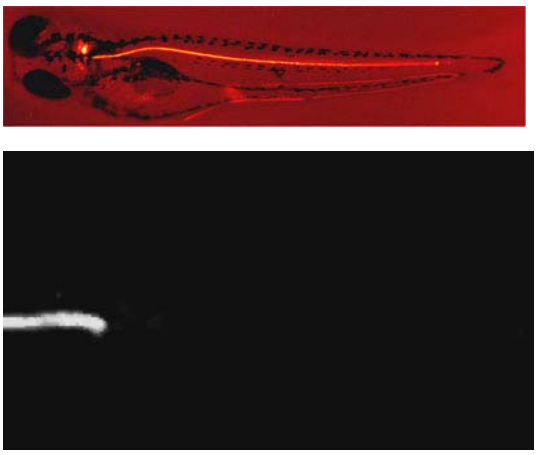
- **Characteristics of APs**
  - How does strength vary?
    - Always the same! → All-or-None Law
    - Does not decrease during propagation
  - How are stronger stimuli recognized?
    - Faster generation of APs → ↑Frequency
    - More neurons fire simultaneously
  - What determines the speed of APs?
    - Myelination
    - Neuron diameter (↑ diameter →↓ Resistance to local current → ↑ Speed)
    - Large myelinated fibers: 120 m/sec (432 km/hr) → urgent information
    - Small unmyelinated fiber: 0.7 m/sec (2.5 km/hr) → slow-acting processes
    - Without myelin the diameter would have to be huge! (50 x larger)



Biomedical Imaging and Applied Optics Laboratory

Regeneration of Nerve Fibers

- **Neurons in the PNS can regenerate**
  - Distal severed portion degenerates
  - Schwann cells pick up the debris
  - Schwann cells remain and form regeneration tube with nerve-growth-enhancing proteins
  - Nerve grows through that tude
- **Neurons in the CNS can NOT regenerate**
  - Oligodendrocytes secrete nerve-growth-inhibiting hormones
  - Necessary to keep a complex system such as the CNS stable (during the end of fetal development and later)
- **Many strategies to regenerate CNS neurons**



Zebra fish axon induced to regenerate
http://www.nbb.cornell.edu/neurobio/Fetcho/regeneration.htm

Επόμενη Διάλεξη …

Διάλεξη 5

Συναπτική Μετάδοση (Synaptic Transmition)