Biosciences in the 21st century

Lecture 1: Neurons, Synapses, and Signaling

Dr. Michael Burger
Outline:

1. Why neuroscience?
2. The neuron
3. Action potentials
4. Synapses
5. Organization of the nervous system
6. Clinical approaches of today and tomorrow
Figure-ground illusions are well known for visual stimuli
http://www.ritsumei.ac.jp/~akitaoka/index-e.html
What did he say?
What did he say?

http://www.media.uio.no/personer/arntm/english.html
Now close your eyes!
But they occur in the auditory system too!
Alzheimer’s Disease

more than 5 million people in the United States living with Alzheimer’s.

The direct and indirect costs of Alzheimer’s and other dementias amount to more than $148 billion annually.

Parkinson’s disease:
3% of population over 65: 1.5 million patients

Hearing Impairment:
Approximately 28 million Americans have a hearing impairment

Approximately 314 in 1,000 people over age 65 have hearing loss and 40 to 50 percent of people 75 and older have a hearing loss.

Paralysis:

2.4 million Americans are paralyzed

Depression:

over 20 million Americans suffer from depression
The **BIG THREE** topics for today:
The **BIG THREE** topics for today:

1. **What is the basis of electrical signaling in neurons?**
The **BIG THREE** topics for today:

1. What is the basis of electrical signaling in neurons?

2. How do neurons “talk” to each other?
The **BIG THREE** topics for today:

1. What is the basis of electrical signaling in neurons?

II. How do neurons “talk” to each other?

III. How do neurons encode information?
The neuron is the “unit of processing” for the nervous system.
The cell membrane is a phospholipid bilayer
The cell membrane is a phospholipid bilayer.
Cell membranes store Voltage

Outside: Extracellular

Inside: Cytoplasmic

Positive

Negative

$V_{\text{membrane}} = -60 \text{ mV}$
**The inside of the cell is usually more negative than the outside by about -60 mV.**
This “resting” voltage depends on ion distribution, and ions *in general* cannot cross the membrane.

The diagram illustrates the distribution of ions across the membrane:

- **Extracellular** side:
  - Na$^+$
  - K$^+$
  - Cl$^-$
  - Ca$^{++}$

- **Cytoplasmic** side:
  - Na$^+$
  - K$^+$

Note: Cl$^-$ is present both inside and outside the cell, but it is not marked inside the cell in the diagram. Organic anions (An$^-$) are also present inside the cell, typically in the form of proteins or other organic compounds.
The cell membrane contains proteins, some of which are channels for charged particles.
Two (of many) membrane protein types:

Ligand gated  
(chemically gated)

Voltage gated
How does an electrical signal occur in a neuron?

Na+

Extracellular

K+

Cytoplasmic

Na+ channel

K+ channel
How does an electrical signal occur in a neuron?

**Na**

FIRST, WE GIVE THE **Na**+ CHANNEL A STIMULUS
Cytoplasmic

Extracellular

Na^+

K^+
Cytoplasmic

Extracellular

Na^+

K^+

Voltage gated K^+ channel

Voltage
One more detail....

The voltage change travels...
The basis of propagation...
Action Potential Summary:

1. Na+ channels open/Na flows into the cell
2. Na+ channels close while K+ channels are opening
3. K+ flow out of the cell dominates
How do neurons “talk” to each other?
Step 1: Depolarization of the axon terminal
Step 2: Voltage dependent Ca++ entry
Step 3: Ca++ dependent vesicle fusion
Step 4: transmitter release
Step 5: Activation of ligand gated channel
Step 6: Na+ flux/dendrite depolarization
Step 5: Activation of ligand gated channel
Step 6: Na+ flux/dendrite depolarization
Step 7: Action Potential is regenerated postsynaptically
Very large auditory synapse
Stain in red marks postsynaptic receptors
Evaluating Neural responses
Evaluating Neural responses

Presynaptic neuron

Electrode

Postsynaptic neuron
Evaluating Neural responses

Presynaptic neuron

Electrode

Amplifier

Action Potential

Postsynaptic neuron
How do neurons encode information?

there are two simple ways.....
with action potential TIMING....

no sound

evoked

100 ms tone
...and Neurons signal by changing their firing rate

![Graph showing intensity (dB SPL) vs. 100 ms tone activity.]}
Spike Rate increases with Intensity

- Stimulus Intensity
- Spike Rate
What we learned today:

1. Neurons and glia: characteristics and function
2. Ionic basis of electrical signaling
3. Basics of chemical synaptic signaling
4. How neural activity is recorded
5. How neural activity relates to information processing
Next time....

Brain organization

New technology for therapy