Biosciences in the 21st century

Lecture 1: Neurons, Synapses, and Signaling

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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
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!
Figure-ground illusions are well known for visual stimuli.
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 neuron is the “unit of processing” for the nervous system.
The cell membrane is a phospholipid bilayer
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Cell membranes store Voltage

Outside: Extracellular

Inside: Cytoplasmic

$V_{membrane} = -60 \text{ mV}$
This “resting” voltage depends on ion distribution, and ions *in general* cannot cross the membrane.

This diagram illustrates the distribution of ions across a membrane:
- **Na⁺** (sodium ions) in the extracellular and cytoplasmic compartments.
- **K⁺** (potassium ions) in the cytoplasmic compartment.
- **Cl⁻** (chloride ions) in the extracellular compartment.
- **Ca²⁺** (calcium ions) in the extracellular compartment.
- **An⁻** (organic anions; i.e., proteins) in the cytoplasmic compartment.
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⁺ channel

K⁺ channel
Cytoplasmic

Extracellular

Na⁺

K⁺
Cytoplasmic

Extracellular

Na+

K+

Membrane

Channel
Cytoplasmic

Extracellular

Na+

K+

Voltage gated K+ channel

Voltage
To the board!
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
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

Synaptic Transmission
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 receptor markers
Evaluating Neural responses

neuron
Evaluating Neural responses

neuron

+
Evaluating Neural responses
How do neurons encode information?
Neurons signal in repeatable/predictable ways...

no sound

evoked

100 ms tone

with action potential timing....
...and Neurons signal by changing their firing rate
What we learned today:

Neurons and glia: characteristics and function

Ionic basis of electrical signaling

Basics of chemical synaptic signaling

How neural activity is recorded

How neural activity relates to information processing
Next time....

Brain organization

New technology for therapy