Neurophysiology and Neurochemistry Review
Cellular Membrane

Phospholipid Bilayer

Hydrophilic

Hydrophobic

Polar Group

Phosphate

Glycerol

Fatty acid chain

Fatty acid chain

Hydrophilic Head (Polar)

Hydrophobic Tails (Non Polar)
Resting membrane potential (-70mV)

There is a larger concentration of positive ions outside the membrane compared to inside.

Forces affecting this potential:

- **Diffusion**
- **Electrostatic pressure**
- **Sodium (Na\(^+\))/Potassium (K\(^+\)) pump**
K+ is higher inside the cell than outside so diffusion forces it outside, but electrostatic pressure moves it inside. Cl- has the opposite situation but is also kept in balance.

Na+ is higher outside the cell than inside so diffusion forces it inside AND electrostatic pull ALSO moves it inside. BUT why isn’t the membrane potential positive then???

The Sodium/Potassium pump pumps Na+ outside the cell and K+ into the cell (against their concentration gradients) to keep membrane potential negative.
The Action Potential

When a threshold is reached (-55 mV), voltage gated Na\(^+\) channels open and Na\(^+\) rushes into the cell causing **depolarization**.

Voltage gated K\(^+\) channels open but after a brief lag.

Voltage gated Na\(^+\) channels close causing **repolarization**.

Voltage gated K\(^+\) channels close but also after a lag inducing a brief **hyperpolarization**.

Membrane returns to rest.
The Action Potential

**All-or-none law**—the strength of the action potential is independent of the intensity of the stimulus that elicits it. Action potential is always the same size.

Coding of intensity (a minor ache vs. a broken bone) is by the **firing rate (rate law)** of a neuron and by the number of neurons firing.
Action potentials are the same height at axon terminals as they are at the axon hillock. Every action potential is the same height.

A neuron can generate a greater number of action potentials but it cannot generate bigger or smaller action potentials.
In myelinated axons, action potentials appear to jump from one node of Ranvier to the next.

That’s because the myelinated segment has no voltage-gated Na$^+$ channels.

Na$^+$ entering at a previous node sets up a current that flows passively along the myelinated segment until it reaches the next node.
Release of aqueous neurotransmitter molecules is the principal means by which one neuron communicates with other neurons.

This requires **fusion of synaptic vesicles** with the presynaptic membrane (requires calcium influx).

Transmitter molecules then diffuse across the synaptic cleft and bind to **protein receptors** in the postsynaptic membrane.
Termination of neurotransmitter action

Termination of neurotransmitter effects can be done in one of three ways:

- **Diffusion** (passive)
- **Enzymatic degradation**
- **Reuptake**

Remember that these are potential drug targets e.g. Acetylcholinesterase inhibitor (Aricept) or Selective Serotonin Reuptake Inhibitor (Prozac)
Imaging the Human Brain

Human Neuropsychology
Bio Sci N173 / Psych 163C / Psy Beh 162N

Michael A. Yassa
Lecture 3B
Electroencephalographic (EEG) Recording

Discovered by Hans Berger in the 1930s, EEG records electrical potentials or “brain waves” in the brain.

It has very low spatial resolution but high temporal resolution.

It is typically used for sleep studies, anesthesia monitoring and recording seizure activity.

1. Electrodes are attached to the skull, corresponding to specific areas of the brain.

2. Polygraph electrodes are connected to magnets, which are connected to pens...

3. ...that produce a paper record of electrical activity in the brain. This record indicates a relaxed person.
Event-Related Potentials (ERPs)

Brief change in a slow-wave EEG signal in response to a discrete sensory stimulus is classified as an ERP. Stimulus is presented repeatedly and the recorded responses are averaged.
Transcranial Magnetic Stimulation

Stimulation of the brain using a small wire coil in the shape of a figure 8. Largely noninvasive but can cause seizures in rare cases. It can be used to temporarily knock out or enhance function in certain regions of the brain (thus can demonstrate causality).

Now being used as a treatment for movement disorders, chronic pain, and depression.
Computerized Tomography (CT Scans)

Produces an image of the brain by shooting a narrow beam of x-rays from all angles to produce a cross-sectional image.

CT scanning of the head is typically used to detect infarction, tumors, calcifications, hemorrhage and bone trauma.
CT Cerebral Angiography

Substance that absorbs X-rays (iodine) is injected into the bloodstream through a catheter. This produces an excellent image of the blood vessels, but it’s pretty invasive. Can help diagnose vascular abnormalities, aneurysms, clots, strokes,
Magnetic Resonance Imaging (MRI)

Produces a static image of the brain by passing a strong magnetic field through the brain, followed by a radio wave, then measuring the energy emitted from hydrogen atoms.
fMRI capitalizes on two important facts:

1. Neural activity is metabolically demanding and requires **oxygen** to move from the blood into active neurons.

2. **Oxygenated** and **deoxygenated hemoglobin** have different magnetic properties, and the **contrast** between the two can be used as a proxy for neural activity (blood-oxygenation-level-dependent i.e. BOLD) signal.
A small amount of radioactively labeled water is injected into a subject. Active areas of the brain use more blood and thus have more radioactive labels.

Positrons from the radioactivity are released; they collide with electrons in the brain, and photons (a form of energy) are produced, exit the head, and are detected.
How is PET used to study function?

Stimulation - Control = Difference

Individual difference images

Mean difference image
Diffusion Tensor Imaging (DTI)

Water molecules in your body are constantly in motion in random directions.

Whenever there’s structure (e.g. axons) that constrains the movement, movement becomes more directional (anisotropic). DTI measures the directionality of water diffusion along these “highways”.

Information can be used to reconstruct white matter pathways (tractography).