

Action Potentials – Lecture Handout

ES.S10 DATB, 2013-03-11

I suggest you write notes in the blank spaces and margins

Outline:

- How action potentials work
- Epilepsy and anticonvulsants
- Shock therapies
- Local anesthetics (e.g. Novocaine)
- Alcohol and alcohol antagonists

Cocaine:

Heavy cocaine use can cause sudden death. Here is why:

- Mental stimulation: Encourages vigorous physical activity
- Increases heart rate (via the sympathetic nervous system)
- Narrows blood vessels, especially in the heart (vasoconstriction)
- Increases blood pressure, thus increasing the load on the heart
- Numbing: Blocks signals within the heart

Cocaine causes localized numbing, it is a local anesthetic. Novocaine is named after cocaine because Novocaine also causes numbness. (Side note: Novocaine is a brand name for procaine, and procaine is no longer used. Dentists today mostly use lidocaine and imprecisely refer to it “Novocaine”.)

Cocaine causes numbing by blocking action potentials. Action potentials are used by the heart to synchronize contraction, but are also used by nerves and the brain.

How Action Potentials Work:

Definition: An action potential is a burst of electrical activity, it lasts about a millisecond (0.001 second). Action potentials convey information within the brain.

Important: I have decided to refrain from fully explaining action potentials in this course. You can learn the details in the following ways:

1. Email me
2. See the [lecture slides](#) for the course.
3. 7.012 and 7.013 cover it to a limited extent
4. 9.01 covers it very well ([OCW site for 9.01](#))
5. 9.09 covers it much more thoroughly ([OCW site for 9.09](#))
6. Wikipedia is especially helpful to fill in the gaps
7. Watch the videos from [this Coursera class](#)
8. I will hopefully post the Coursera videos

Excitatory: Excitatory events tend to **cause** action potentials.

Inhibitory: Inhibitory events tend to **inhibit** action potentials, inhibitory events make action potentials less likely and less frequent.

Depolarizing: Depolarizing a neuron is **excitatory**. When a neuron is sufficiently depolarized, it will fire an action potential.

Hyperpolarizing: Hyperpolarizing a neuron is **inhibitory**.

Sodium: When sodium flows, it is excitatory. Sodium flows into the neuron and depolarizes it.

Potassium: When potassium flows, it is inhibitory. Potassium flows out of the neuron and hyperpolarizes it.

Chloride: When chloride flows, it is inhibitory. Chloride flows into the neuron and hyperpolarizes it.

Glutamate: Glutamate is the major **excitatory** neurotransmitter, glutamate causes **sodium** channels to open. Specifically, glutamate opens a number of ligand-gated ion channels called the NMDA, AMPA, and kainate receptors.

GABA: GABA is the major **inhibitory** neurotransmitter, GABA causes **chloride** channels to open. Specifically, GABA opens a ligand-gated ion channel called the GABA_A receptor.

Epilepsy and Anticonvulsants:

Epileptic people have seizures. A seizure is caused by excessive action potentials. Excitatory events and excitatory drugs tend to cause seizures.

Anticonvulsants are drugs that prevent seizures. See the slides for examples and mechanisms.

Shock Therapies:

Hypothesis: Perhaps fever is beneficial, and syphilis patients who don't have fevers could improve if they *did* have a fever.

1917: Dr. Julius Wagner von Jauregg intentionally gives malaria to patients with neurosyphilis, to induce a fever. He noticed that if they have febrile seizures, they get less crazy and less depressed. He won the 1927 Nobel Prize for this work.

Hypothesis: Maybe crazy people's brain cells are tired and need to rest. Let's induce a coma to provide that rest.

1927: Dr. Manfred J. Sakel gives schizophrenic patients insulin to induce coma, many of them are improved upon waking. Those who have seizures along with their coma improve the most.

Hypothesis: I've never seen a schizophrenic epileptic, therefore the diseases must be mutually antagonistic. (This theory is dead wrong and Dr. Meduna's observations were due to coincidence.)

1934: Dr. Ladislaus von Meduna gives schizophrenic patients various convulsants to induce seizure. He tried camphor, strychnine, thebaine, pilocarpine, and pentylenetetrazol (a.k.a. metrazol, PTZ).

Hypothesis: Dr. Meduna's drug-induced seizures are incredibly dangerous. Let's try using electricity instead.

1937: Dr. Ugo Cerletti uses electric shocks to induce seizures in schizophrenic patients.

Shock therapies have changed over the past 75 years:

Shock therapy was long used for schizophrenia, but it is actually not effective at all. It is mildly useful as a punishment and a sedative.

Shock therapy is very useful for depression.

Shock therapy refers to any therapy that induces seizures. It can use drugs or electricity.

ECT or electroconvulsive therapy refers specifically to seizures induced by electricity. It is a type of shock therapy.

Paralytics (including succinyl choline and vecuronium) are now used to paralyze all skeletal muscles, thus preventing broken bones.

General anesthesia is now given before the seizure in order to prevent panic and pain. Prior to the widespread use of anesthesia, shock therapy was reported to be extremely terrifying.

If the electric shock is applied only to one half of the head, or only to the front, then it minimizes memory loss.

As the procedure is done today (with anesthesia and paralytics), memory loss and headache are the primary side effects of ECT.

ECT was used by the famous **frontal lobotomy** advocate, Walter Freeman. Dr. Freeman would use ECT to anesthetize the patient, then he would use an instrument resembling an ice pick to perform the lobotomy. He used ECT instead of traditional anesthetic drugs because he was not actually a surgeon, and because he liked to perform the lobotomies in mental asylums that lacked proper hospital equipment.

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