

Experiment AN-2: Frog Sciatic Nerve Compound Action Potential

Background

The interior of a cell is negatively charged with respect to the outside, and the magnitude of the potential difference is usually between 50 and 90 mV. Some cells, like those in nerves and muscles, can transiently reverse their membrane potentials. This event is called an action potential and takes place in milliseconds. During this process, the membrane potential goes from negative to positive and back to negative again ([Figure AN-2-B1](#)).

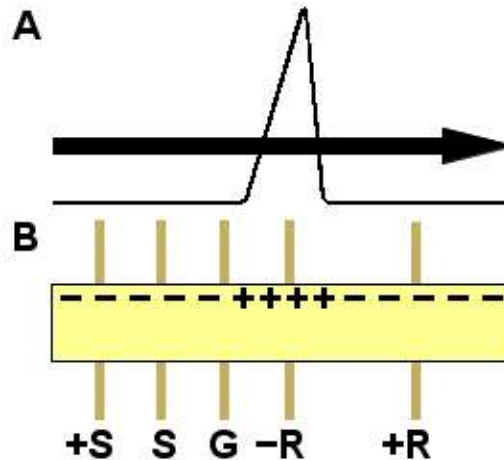


Figure AN-2-B1: Diagram of the change in membrane polarity (B) that occurs in a nerve cell (neuron) as an action potential (A) sweeps down the inside of the cell from the stimulating electrodes (+S, -S) past the ground (G) to the recording electrodes (-R, +R).

In the resting cell, the permeability of the membrane to potassium (P_K) is much greater than its permeability to sodium (P_{Na}). Stimulation, like synaptic activity coming from other nerve cells, can depolarize (make less negative) the cell membrane. Sodium channels in the cell membrane are sensitive to membrane depolarization and they respond by opening, which increases the membrane's permeability to sodium. If the depolarization reaches or exceeds a certain level (threshold), an action potential is produced. Action potentials develop because of a regenerative, positive feedback cycle. As the cell's permeability to sodium increases, sodium conductance increases, and increased sodium conductance leads to greater depolarization of the membrane. As depolarization increases, sodium permeability increases again, and more voltage-sensitive channels open. With more channels open, sodium conductance and membrane depolarization increase as the membrane potential moves toward the equilibrium potential for sodium.

But, before the equilibrium potential for sodium is reached, two other events occur: the voltage-sensitive sodium channels close soon after they open, and the voltage-sensitive potassium channels open. With the potassium channels open, potassium ions leave the cell and cause the membrane to repolarize (hyperpolarize) towards its resting level. This process of membrane hyperpolarization closes the voltage-sensitive potassium channels and re-primed the sodium channels so that they are ready to open once more. During this process, the axon is unable to fire another action potential and the refractory period occurs at this time.

Propagation of the action potential from the site of initiation to other locations along the nerve cell is caused by the positive charges in the cell leaking to an adjacent (unstimulated) region and depolarizing that region enough to create an action potential there. In this way, the signal moves from one region of the axon to the adjacent one, and ultimately to the end of the axon. Some vertebrate axons are myelinated; the axon is covered with a series of Schwann cells, a type of glial cell which electrically insulates the axon. The spaces between adjacent Schwann cells are called the nodes of Ranvier, and they are the only regions along the axon where the membrane is exposed to the extracellular fluid. The myelin insulation prevents the currents associated with action potentials from leaking out of the membrane until they reach a node. So, action potentials take place only at the nodes in myelinated cells.

In this laboratory you will record action potentials from the sciatic nerve of a frog. Each nerve contains hundreds of axons with different diameters, thresholds, and degrees of myelination. The large, myelinated axons with the fastest conduction velocities are known as Type A fibers, which are further subdivided into α , β , γ , and δ types. Type B fibers are also myelinated, but have smaller diameters and slower conduction velocities. Type C fibers are very small, unmyelinated axons. When a large stimulus is delivered to the nerve, many axons respond and the recorded potential is the summation of all the axons firing. This potential is known as the compound action potential (CAP).

In this experiment, students will examine certain principles associated with nerve conduction:

- Compound action potential: observing the one or more populations of different fiber types.
- Stimulus-response/axon recruitment: observing how the nerve response changes with increased stimulus voltage.
- Conduction velocity: measuring the speed at which action potentials propagate down the axons.
- Bidirectionality: determining whether axons conduct in both directions.
- Refractoriness: observing how stimulus frequency affects the amplitude of compound action potentials.
- Strength-duration: observing how the amplitude of a stimulus required to stimulate axons is related to the duration of the stimulus.