VI Semester
PHYSIOLOGICAL PSYCHOLOGY
Unit II

Transmission of nerve impulse

In order to understand more fully the electrical potentials of axons, scientists have used the giant squid axon which is about 100 times larger than the mammalian axon. This large axon controls emergency response; sudden contraction of the mantle, which squirts water through a jet and propels the squid away from the source of danger. The giant squid axon is placed isolated in a dish of seawater for a day or two. To measure the electrical charges generated by an axon, a pair of electrodes is used. One of the electrodes is a simple wire that is placed in the seawater. The other one is used to record the message from the axon. When these electrodes are placed, it is discovered that the inside of the axon is negatively charged and the outside is positively charged. The difference in charge is 70mV. This electrical charge is called membrane potential. The term potential refers to a stored-up source of energy – in this case, electrical energy.

The message that is conducted down the axon consists of a brief change in the membrane potential. However, this change occurs very rapidly – too rapidly that it is very difficult to measure with a voltmeter. Therefore, to study the message, an oscilloscope is used which measures voltages, but also produces reorder of these voltages, graphing them in as a function of time. Once microelectrode is inserted into the axon, the oscilloscope draws a straight horizontal line at -70mV, as long as the axon is not disturbed. This electrical change across the membrane is called resting potential – the membrane potential measured while the membrane is at rest. When the resting potential is disturbed by an electrical stimulator – the stimulator passes current through another microelectrode that have been inserted in the axon; the membrane produces a depolarization – that is, it takes away some of the electrical charge across the membrane near the electrodes, reducing the membrane potential. Depolarization basically occurs by application of the positive charge to the outside.

As stimulator strength increases, depolarization increase and suddenly there is a reversal, that is, the inside becomes positive and the outside becomes negative. Then the membrane potential quickly returns to normal, but first it overshoots the resting potential, becoming hyperpolarized – more polarized than normal – for a short time. The whole process takes about 2msec – called action potential. It constitutes the message carried by the axon from the cell body to the terminal buttons. The voltage level that triggers an action potential is called the threshold of excitation.

The electrical charge is a result of two opposing forces – diffusion and electrostatic pressure.

1. Diffusion – this refers to movement of molecules from regions of high concentration to regions of low concentration. E.g. sugar in water.
2. Electrostatic pressure – this refers to the attractive force exerted by forces between ions (charged particles) such as cations (+ve) and anions (-ve). E.g. NaCl (sodium chloride or common salt) in water.

Ions in the extracellular and intracellular

The fluid within cells (intracellular fluid) and the fluid surrounding them (extracellular fluid) contain different ions. The force of diffusion and electrostatic pressure contributed by these ions give rise to the membrane potential. Two ions are responsible: sodium (Na+) and potassium (K+). An unequal distribution of these two ions occurs on the two sides of a nerve cell membrane because carriers actively transport these two ions: sodium from the inside to the outside and potassium from the outside to the inside. As a result of this active transport mechanism (commonly referred to as the SODIUM - POTASSIUM PUMP), there is a higher concentration of sodium on the outside than the inside and a higher concentration of potassium on the inside than the outside.

The nerve cell membrane also contains special passageways for these two ions that are commonly referred to as GATES or CHANNELS. Thus, there are SODIUM GATES and POTASSIUM GATES. These gates represent the only way that these ions can diffuse through a nerve cell membrane.

IN A RESTING NERVE CELL MEMBRANE, all the sodium gates are closed and some of the potassium gates are open. As a result, sodium cannot diffuse through the membrane & largely remains outside the membrane. However, some potassium ions are able to diffuse out. Overall, therefore, there are lots of positively charged potassium ions just inside the membrane and lots of positively charged sodium ions plus some potassium ions on the outside. THIS MEANS THAT THERE ARE MORE POSITIVE CHARGES ON THE OUTSIDE THAN ON THE INSIDE. In other words, there is an unequal distribution of ions or a resting membrane potential. This potential will be maintained until the membrane is disturbed or stimulated. Then, if it's a sufficiently strong stimulus, an action potential will occur.

An action potential is a very rapid change in membrane potential that occurs when a nerve cell membrane is stimulated. Specifically, the membrane potential goes from the resting potential (typically -70 mV) to some positive value (typically about +30 mV) in a very short period of time (just a few milliseconds). The stimulus causes the sodium gates (or channels) to open and, because there's more sodium on the outside than the inside of the membrane, sodium then diffuses rapidly into the nerve cell. All these positively-charged sodium rushing in causes the membrane potential to become positive (the inside of the membrane is now positive relative to the outside). The sodium channels open only briefly, then close again. The potassium channels then open, and, because there is more potassium inside the membrane than outside, positively-charged potassium ions diffuse out. As these positive ions go out, the inside of the membrane once again becomes negative with respect to the outside.

Threshold stimulus & potential

- Action potentials occur only when the membrane in stimulated (depolarized) enough so that sodium channels open completely. The minimum stimulus needed to achieve an action potential is called the threshold stimulus.
- The threshold stimulus causes the membrane potential to become less negative (because a stimulus, no matter how small, causes a few sodium channels to open and allows some positively-charged sodium ions to diffuse in).
- If the membrane potential reaches the threshold potential (generally 5 - 15 mV less negative than the resting potential), the voltage-regulated sodium channels all open. Sodium ions rapidly diffuse inward, & depolarization occurs.

All-or-None Law - action potentials occur maximally or not at all. In other words, there's no such thing as a partial or weak action potential. Either the threshold potential is reached and an action potential occurs, or it isn't reached and no action potential occurs.

Refractory periods:

ABSOLUTE -

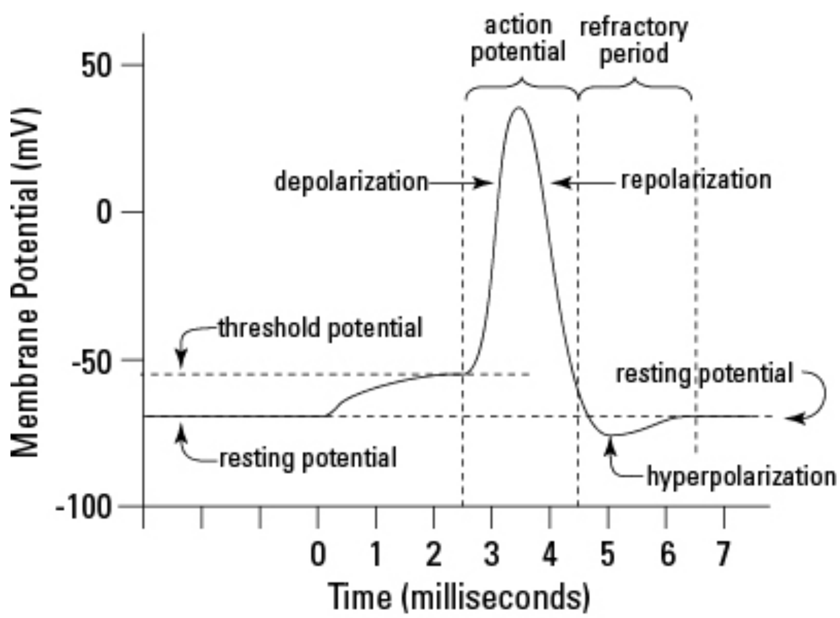
- During an action potential, a second stimulus will not produce a second action potential (no matter how strong that stimulus is)
- corresponds to the period when the sodium channels are open (typically just a millisecond or less)

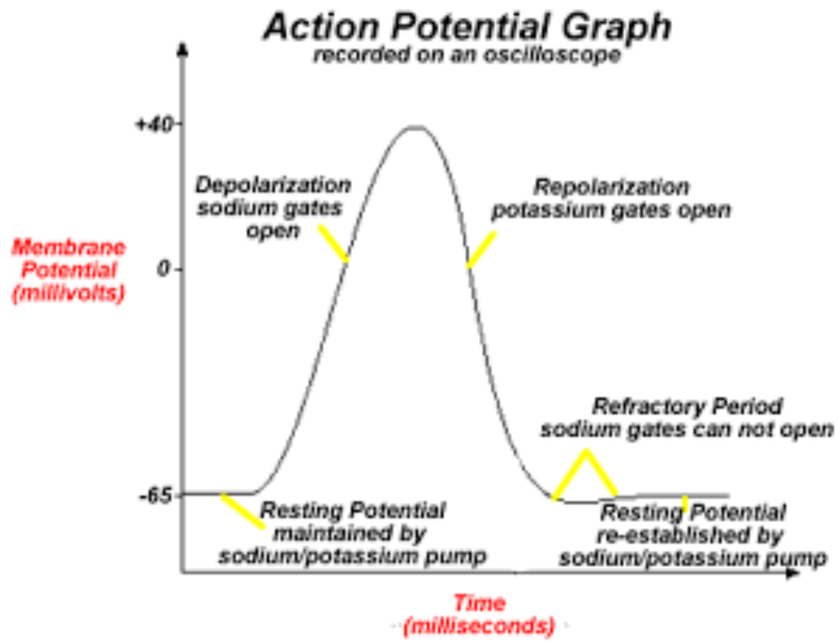
RELATIVE -

- Another action potential can be produced, but only if the stimulus is greater than the threshold stimulus
- corresponds to the period when the potassium channels are open (several milliseconds)
- the nerve cell membrane becomes progressively more 'sensitive' (easier to stimulate) as the relative refractory period proceeds. So, it takes a very strong stimulus to cause an action potential at the beginning of the relative

refractory period, but only a slightly above threshold stimulus to cause an action potential near the end of the relative refractory period

The absolute refractory period places a limit on the rate at which a neuron can conduct impulses, and the relative refractory period permits variation in the rate at which a neuron conducts impulses. Such variation is important because it is one of the ways by which our nervous system recognizes differences in stimulus strength.





Reference:
Carlson, N. R. (2004). Foundations of Physiological Psychology. 6th Edition. Allyn & Bacon

Kalat, J. W. (2007). Biological Psychology. 9th Edition. Brooks/Cole Publishers.

Leukel, F. (2005). Introduction to Physiological Psychology. 3rd Edition. CBS Publisher.

Rosenzweig, M. R., Leiman, A. L. & Breedlove, S. R. (2001). Biological Psychology. 3rd Edition. Sinauer Associates Inc.