ROHINI
COLLEGE OF ENGINEERING AND TECHNOLOGY
Approved by AICTE and affiliated to Anna University Chennai (An ISO Certified Institution)
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DEPARTMENT OF BIOMEDICAL ENGINEERING

BM3491 Biomedical Instrumentation

UNIT-I ELECTRODE CONFIGURATIONS

1.1 Origin of bio potential and its propagation:

1.1.1 Introduction:

Most of the physiological processes were accompanied with electrical changes. This discovery formed the basis of the explanation of the action of living tissues in terms of bioelectric potentials. Bioelectric potentials are generated at a cellular level and the source of these potentials is ionic in nature. A cell consists of an ionic conductor separated from the outside environment by a semipermeable membrane which acts as a selective ionic filter to the ions. This means that some ions can pass through the membrane freely where as others cannot do so. All living matter is composed of cells of different types. Surrounding the cells of the body are body fluids, which are ionic and which provide a conducting medium for electric potentials. The principal ions involved with the phenomena of producing cell potentials are sodium (Na+), potassium (K+) and chloride (Cl–).

1.1.2 Resting and Action Potentials:

i. Certain types of cells within the body, such as nerve and muscle cells, are encased in a semipermeable membrane that permits some substances to pass through the membrane while others are kept out.
ii. Surrounding the cells of the body are the body fluids. These fluids are conductive solutions containing charged atoms known as ions. The principal ions are sodium (Na+), potassium (K+), and chloride (C-).
iii. The membrane of excitable cells readily permits entry of potassium and chloride ions but effectively blocks the entry of sodium ions. Since the various ions seek

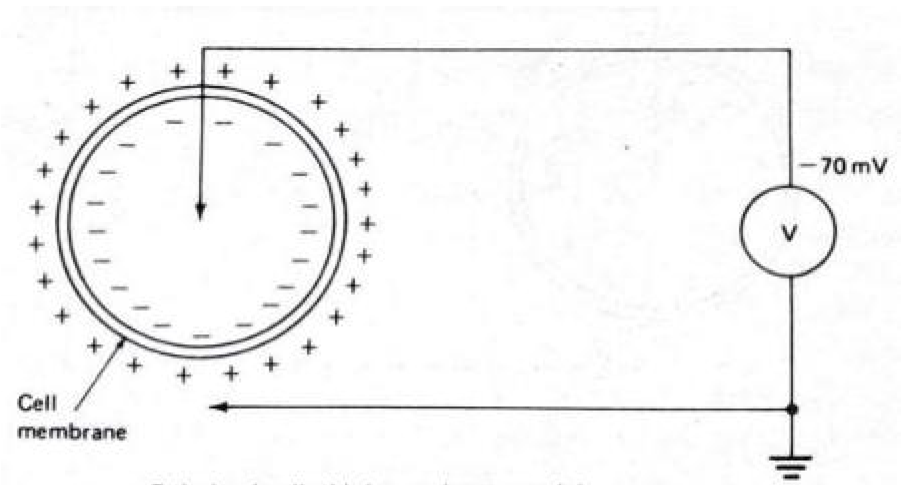
a balance between the inside of the cell and the outside, both according to concentration and electric charge, the inability of the sodium to penetrate the membrane results in two conditions.

iv. First, the concentration of sodium ions inside the cell becomes much lower than in the intercellular fluid outside. Since the sodium ions are positive, this would tend to make the outside of the cell more positive than the inside.

v. Second, in an attempt to balance the electric charge, additional potassium ions, which are also positive, enter the cell, causing a higher concentration of potassium on the inside than on the outside. This charge balance cannot be achieved, however, because of the concentration imbalance of potassium ions. Equilibrium is reached with a potential difference across the membrane, negative on the inside and positive on the outside. This membrane potential is called the **resting potential of the cell** and is maintained until some kind of disturbance upsets the equilibrium.

vi. Since measurement of the membrane potential is generally made from inside the cell with respect to the body fluids, the resting potential of a cell is given as negative. Research investigators have reported measuring membrane potentials in various cells ranging from - 60 to - 100 mV. A cell in the resting state is said to be polarized cell.

vii. When a section of the cell membrane is excited by the flow of ionic current or by some form of externally applied energy, the membrane changes its

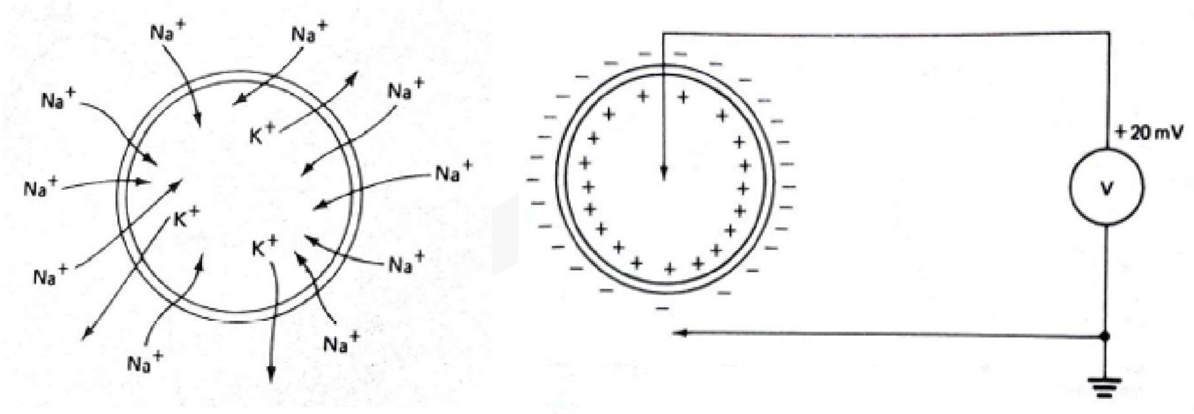


Polarized cell with its resting potential

characteristics and begins to allow some of the sodium ions to enter. This movement of sodium ions into the cell constitutes an ionic cur- rent flow that further reduces the barrier of the membrane to sodium ions. The net result is an avalanche effect in which sodium ions literally rush into the cell to try to reach a balance with the ions outside.

viii. At the same time potassium ions, which were in higher concentration inside the cell during the resting state, try to leave the cell but are unable to move as rapidly as the sodium ions. As a result, the cell has a slightly positive potential on the in- side due to the imbalance of potassium ions. This potential is known as the **action potential** and is approximately + 20 mV.

ix. A cell that has been excited and that displays an action potential is said to be **depolarized**; the process of changing from the resting state to the action potential is called **depolarization**.



x. Once the rush of sodium ions through the cell membrane has stopped (a new state of equilibrium is reached), the ionic currents that lowered the barrier to sodium ions are no longer present and the membrane reverts back to its original, selectively permeable condition, wherein the passage of sodium ions from the outside to the inside of the cell is again blocked. Were this the only effect, however, it would take a long time for a resting potential to develop again.

xi. But such is not the case. By an active process, called a ***sodium pump***, the sodium ions are quickly transported to the outside of the cell, and the cell again becomes polarized and assumes its resting potential. This process is called **repolarization**. The rate of pumping is directly proportional to the sodium concentration in the cell.

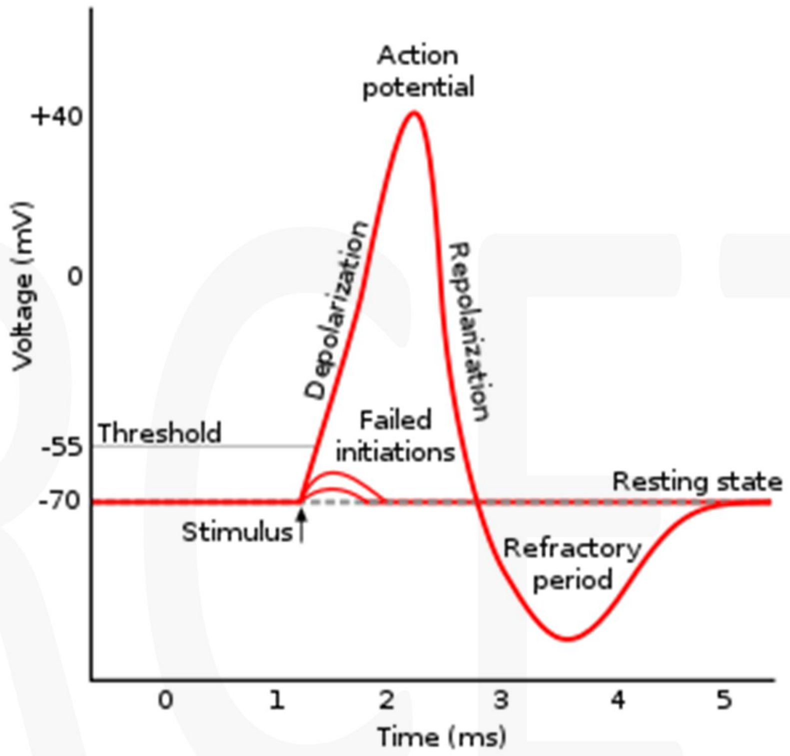


Fig. Waveform of the action potential

xii. Figure shows a typical action-potential waveform, beginning at the resting potential, depolarizing, and returning to the resting potential after repolarization. The time scale for the action potential depends on the type of cell producing the potential. In nerve and muscle cells, repolarization occurs so rapidly following depolarization that the action potential appears as a spike of as little as 1 m.sec. total duration. Heart muscle, on the other hand, repolarizes much more slowly, with the action potential for heart muscle usually lasting from 150 to 300 m.sec.

xiii. Regardless of the method by which a cell is excited or the intensity of the stimulus (provided it is sufficient to activate the cell), the action potential is always the same for any given cell. This is known as the **all-or-nothing law**.

xiv. Following the generation of an action potential, there is a brief period of time during which the cell cannot respond to any new stimulus. This period, called the **absolute refractory period**, lasts about 1 msec in nerve cells.

xv. Following the absolute refractory period, there occurs a **relative refractory period,** during which another action potential can be triggered, but a much stronger stimulation is required. In nerve cells, the relative refractory period lasts several milliseconds. These refractory periods are believed to be the result of after-potential.

1.1.3 Propagation of Action Potentials:

i. When a cell is excited and generates an action potential ionic currents begin to flow.
ii. This process can, in turn, excite neighbouring cells or adjacent areas of the same cell.
iii. In the case of a nerve cell with a long fiber, the action potential is generated over a very small segment of the fiber's length but is propagated in both directions from the original point of excitation. In nature, nerve cells are excited only near their ** input end'*
iv. As the action potential travels down the fiber, it cannot reexcite the portion of the fiber immediately upstream, because of the refractory period that follows the action potential.
v. The rate at which an action potential moves down a fiber or is propagated from cell to cell is called the **propagation rate**. In nerve fibers the propagation rate is also called the nerve conduction rate, or **conduction velocity**. This velocity varies widely, depending on the type and diameter of the nerve fiber. The usual velocity range in nerves is from 20 to 140 meters per second (m/sec).
vi. Propagation through heart muscle is slower, with an average rate from 0.2 to 0.4 m/sec. Special time-delay fibers between the atria and ventricles of the heart cause action potentials to propagate at an even slower rate, 0.03 to 0.05 m/sec.

1.1.4 The Bioelectric Potentials:

i. To measure bioelectric potentials, a transducer capable of converting ionic potentials and currents into electric potentials and currents is required.

ii. Such a transducer consists of two electrodes, which measure the ionic potential difference between their respective points of application.

iii. Measurement of individual action potentials can be made in some types of cells, such measurements are difficult because they require precise placement of an electrode inside a cell.

iv. The more common form of measured biopotentials is the combined effect of a large number of action potentials as they appear at the surface of the body, or at one or more electrodes inserted into a muscle, nerve, or some part of the brain.

v. The exact method by which these potentials reach the surface of the body is not known.

vi. According to theory, the surface pattern is a summation of the potentials developed by the electric fields set up by the ionic currents that generate the individual action potentials.

vii. This theory, although plausible, fails to explain a number of the characteristics indicated by the observed surface patterns.

viii. They can be measured as specific bioelectric signal patterns that have been studied extensively and can be defined quite well. The designation of the wave-form itself generally ends in the suffix gram, whereas the name of the in-strument used to measure the potentials and graphically reproduce the wave-form ends in the suffix graph. For example, the electrocardiogram (the name of the waveform resulting from the heart's electrical activity) is measured on an electrocardiograph (the instrument).

ix. The source of bioelectric signals are cells which undergo change of state from resting potential to action potential under certain conditions. The change of potential in many cells generate an electric field which fluctuates and, in this process, it is to emit bioelectric signal. ECG and EEG are obtained from the bio signals from heart and brain respectively.

x. The Bioelectric Potentials are

- The Electrocardiogram(ECG)
- The Electroencephalogram(EEG)
- The Electromyogram(EMG)
- The Electroretinogram(ERG)
- The Electro-oculogram(EOG)
- The Electrogastrogram(EGG)

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