Origin of Biopotentials

- Cells transport ions across their membrane leading to ion concentration differences and therefore charge differences - hence generating a voltage.
- Most cell groups in the tissues of the human body do not produce electric voltages synchronously, but more or less randomly. Thus most tissues have a resultant voltage of zero as the various random voltages cancel out.
- When many cells produce voltages synchronously the resultant voltage is high enough to be measurable e.g., EMG - muscle fibre contraction, most cells of the fibre perform the same electric activity synchronously and a measurable electric voltage appears.
- Many organs in the human body, such as the heart, brain, muscles, and eyes, manifest their function through electric activity. The heart, for example, produces a signal called the electrocardiogram or ECG (Figure 74.1a). The brain produces a signal called an electroencephalogram or EEG (Figure 74.1b). The activity of muscles, such as contraction and relaxation, produces an electromyogram or EMG (Figure 74.1c). Eye movement results in a signal called an electrooculogram or EOG (Figure 74.1d), and the retina within the eyes produces the electoretinogram or ERG.

- Measurements of these and other electric signals from the body can provide vital clues as to normal or pathological functions of the organs. For example, abnormal heart beats or arrhythmias can be readily diagnosed from an ECG. Neurologists interpret EEG signals to identify epileptic seizure events. EMG signals can be helpful in assessing muscle function as well as neuromuscular disorders. EOG signals are used in the diagnosis of disorders of eye movement and balance disorders.

- The origins of these biopotentials can be traced to the electric activity at the cellular level. The electric potential across a cell membrane is the result of different ionic concentrations that exist inside and outside the cell. The electrochemical concentration gradient across a semipermeable membrane results in the Nernst potential.

- The cell membrane separates high concentrations of potassium ion and low concentrations of sodium ions (along with other ions such as calcium in less significant proportions) inside a cell and just the opposite outside a cell. This difference in ionic concentration across the cell membrane produces the resting potential.

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- Some of the cells in the body are excitable and produce what is called an action potential, which results from a rapid flux of ions across the cell membrane in response to an electric stimulation or transient change in the electric gradient of the cell. The electric excitation of cells generates currents in the surrounding volume conductor manifesting itself as potentials on the body.
Each cell in the heart produces a characteristic action potential. The activity of cells in the sinoatrial node of the heart produces an excitation that propagates from the atria to the ventricles through well-defined pathways and eventually throughout the heart; this electric excitation produces a synchronous contraction of the heart muscle. The associated biopotential is the ECG.

Electric excitation of a neuron produces an action potential that travels down its dendrites and axon; activity of a massive number of neurons and their interactions within the cortical mantle results in the EEG signal.

Excitation of neurons transmitted via a nerve to a neuromuscular junction produces stimulation of muscle fibers. Constitutive elements of muscle fibers are the single motor units, and their electric activity is called a single motor unit potential. The electric activity of large numbers of single motor unit potentials from groups of muscle fibers manifests on the body surface as the EMG. Contraction and relaxation of muscles is accompanied by proportionate EMG signals.

The retina of the eye is a multilayered and rather regularly structured organ containing cells called rods and cones, cells that sense light and color. Motion of the eyeballs inside the conductive contents of the skull alters the electric potentials. Placing the electrode in the vicinity of the eyes (on either side of the eyes on the temples or above and below the eyes) picks up the potentials associated with eye movements called EOGs. Thus, it is clear that biopotentials at the cellular level play an integral role in the function of various vital organs.

**Biopotentials**

Biopotentials from organs are diverse. Note that all acquisitions are made with the aid of specialized electrodes in which actual design may be customized for specific needs. The most noteworthy features of biopotentials are:

- Small amplitudes (10mV to 10 mV),
- Low frequency range of signals (dc to several hundred hertz)

The most noteworthy problems of such acquisitions are:

- Presence of biological interference (from skin, electrodes, motion, etc.),
- Noise from environmental sources (power line, radio frequency, electromagnetic, etc.).

<table>
<thead>
<tr>
<th>TABLE 74.1</th>
<th>Biopotentials, Specifications, and Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Source</strong></td>
<td><strong>Amplitude (mV)</strong></td>
</tr>
<tr>
<td>ECG</td>
<td>1–5</td>
</tr>
<tr>
<td>EEG</td>
<td>0.001–0.01</td>
</tr>
<tr>
<td>EMG</td>
<td>1–10</td>
</tr>
<tr>
<td>EOG</td>
<td>0.01–0.1</td>
</tr>
</tbody>
</table>