2.11. Electroencephalogram

The largest part of the brain immediately beneath the bones of the cranium is the cerebral cortex. The cerebral cortex is composed of nerve cells (neurons), many of which are connected to each other and connected to other parts of the brain. Electrical activity in the form of nerve impulses being sent and received to and from cortical neurons is always present, even during sleep. In a biological sense (as well as a medical and legal sense), absence of electrical activity in the human cerebral cortex signifies death.

Since the cerebral cortex is just under the cranium, electrodes placed on the scalp above the various regions of the brain can detect the electrical activity associated with functioning neurons. In the case of brain, the electrical activity is generated by the cerebrocortical neurons, namely by the cell bodies and apical dendrites of the large pyramidal cells forming vertical columns in the cortex. The EEG waves are summations of the post-synaptic potentials which are continuously modified by the excitatory and inhibitory influences from the thalamus and from other regions of the brain.

The rhythmic character of the EEG is a result of the synchronous post-synaptic activity of a larger group of subcortical neurons. Subcortical, mainly thalamic pacemaker regions are responsible for this synchronous activity. Stimulation of some thalamic nuclei results in a rhythmic activity of the whole cortex, while lesions of the thalamus put an end to the alpha activity, even when the cortex functions properly. In case of an increase activity of the ascending reticular activating system (ARAS) the high voltage, slow, synchronous activity is transformed into smaller voltage, fast activity. This phenomenon is called desynchronisation, which can be observed when opening the eyes, waking up from sleep and during mental and psychic activity.

The recording of the brain's electrical activity obtained by using electrodes is called electroencephalogram (EEG).

An EEG electrode will mainly detect the activity in the brain region just under it. Nevertheless, the electrodes receive the activity from thousands of neurons. In fact 1mm$^2$ of cortex has more than 100000 neurons. Since each region of the cerebral cortex of an alert person is busy receiving, integrating, and sending many impulses, this activity is detected in EEG.

Four simple periodic rhythms recorded in the EEG are alpha, beta, delta and theta. These rhythms are identified by frequency (Hz or cycles/sec) and amplitude and shape. The amplitudes recorded by scalp electrodes are in the range of microvolts (μV) (Table 2.4).

<table>
<thead>
<tr>
<th>RHYTHM</th>
<th>FREQUENCY (Hz)</th>
<th>AMPLITUDE (μV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha</td>
<td>8-13</td>
<td>20 -200</td>
</tr>
<tr>
<td>Beta</td>
<td>13-30</td>
<td>5-10</td>
</tr>
<tr>
<td>Delta</td>
<td>1-5</td>
<td>20 -200</td>
</tr>
<tr>
<td>theta</td>
<td>4-8</td>
<td>10</td>
</tr>
</tbody>
</table>

Alpha rhythm (a)

In general the alpha waves/rhythm is the prominent EEG wave pattern of an adult who is awake but relaxed with eyes closed. Each region of the brain has a characteristic alpha
rhythm, but a waves of the greatest amplitude are recorded from the occipital and parietal regions of the cerebral cortex. Results from various studies indicate that: females tend to have higher mean frequencies of a waves than males a waves amplitudes are likely to be higher in outgoing subjects a waves amplitudes vary with the subject's attention to mental tasks performed with the eyes closed

In general, amplitudes of a waves diminish when the subjects open their eyes and attentive to external stimuli although some subjects trained in relaxation technique can maintain high alpha amplitude even with their eyes open (Figure 2.8).

With hyperventilation, the overall electrical activity of the brain increases, with the amplitude of the alpha rhythms often increasing as well.

\[
\text{Eyes open} \quad \text{Eyes closed}
\]

**Figure** 2.8. Replacement of the *alpha* rhythm by an asynchronous, low voltage *beta* rhythm when the eyes are opened (after A.C. Guyton & J. Hall, Textbook of Medical Physiology, 2006)

**Beta rhythm (p)**

Beta rhythm occur in individuals who are alert and attentive to external stimuli or exert specific mental effort, or paradoxically, beta rhythms also occur during deep sleep, REM (Rapid Eye Movement) sleep, when the eyes switch back and forth. The amplitude of beta rhythm tends to be lower than alpha rhythm. The beta rhythm represents arousal of the cortex to a higher state of alertness or tension. It may also be associated with remembering or retrieving memories.

**Delta and theta rhythm (5, x)**

Delta and theta rhythms are low-frequency EEG patterns that increase during sleep in the normal adult. As people move from lighter to deeper stages of sleep (prior to REM sleep), the occurrence of alpha waves diminishes and is gradually replaced by the lower frequency theta and then delta rhythms.

Although the delta and theta rhythms are generally most prominent during sleep, there are cases when delta and theta rhythms are recorded from individuals who are awake. For example, theta waves will occur for brief intervals during emotional responses to frustrating events or situations. Delta waves may increase during difficult mental activities requiring concentration. In general, the occurrence and amplitudes of delta and theta waves are highly variable within and between individuals (Figure 2.9).

**Electrode positions and recording of EEG**

Electrode positions have been named according to the region of the brain below that area of the scalp: frontal, central (sulcus), parietal, temporal, occipital. In the bipolar method, the EEG is measured from the a pair of scalp electrodes. The pair of electrodes measures the difference in electrical potential between their two positions above the brain. A third electrode is put on the earlobe as a point of reference, ground, of the body's baseline voltage due to other electrical activities within the body.

EEG is recorded with an electroencephalograf, which is made up of three components: a system for capturing the electric activity of brain, a system for amplification and a system of recording the potentials.
The capture system is represented by the electrodes and their connections with the amplification system. Electrodes are applied on the scalp with some elastic strips. They are placed symmetrically, at a distance of 3-5 cm, in frontal, parietal, temporal, occipital regions, on the median line, in a number of 10-20 electrodes.

Amplification system is made up of an electronic device that can amplify of a few hundred times the differences of potential. The most common electroencephalographs have 8-20 channels of amplification, being possible to record simultaneously the difference of potential from a corresponding number of cerebral regions.

The recording system is made up of a magnetic oscilograph, pens and a special paper, that runs with a constant speed (15-30 mm/sec).

![Beta](image)

![Trteta](image)

Figure 2.9. Different types of brain waves in the normal electroencephalogram (after A.C. Guyton & J. Hall, Textbook of Medical Physiology, 2006)

Applications of EEG

EEG may have many medical applications. It can be used for diagnosing organic malfunctions such as: epilepsy, brain tumor, brain abscess, cerebral trauma, stroke, meningitis, encephalitis and certain congenital conditions, coma, brain death. In spite of this diagnostic value, however, a completely normal EEG is frequently seen where considerable brain damage is present.

The brain wave patterns of infants and children exhibit fast beta rhythms as well as the slower theta and delta rhythms. As children mature into adolescence, the rhythms develop into a characteristic alpha pattern of adulthood. Physiological conditions such as low body temperature, low blood sugar level, high levels of carbon dioxide in the blood can slow down the alpha rhythm; the opposite conditions speed it up.

2.12. Laws of medullary reflexes

The anatomic and functional organization of spinal cord, makes that the amplitude of reflex reactions to the stimulation of exteroceptors to be proportional with the intensity of stimulus.
Materials: frog, frogboard, dissection kit, a stand with hook, filter paper, beakers, solution of sulphuric acid, cone.: 0.1%, 0.5%, 1%, 5% and 10%.

Procedure: the head of frog is removed and the frog is hanged in the stand by passing the mandibula through the hook.

One of the posterior legs is introduced into the beaker, containing different sulphuric acid concentrations (increasing cone.). The amplitude of response (localised initially at the level of toes, extended at the musculature of the leg, involving the opposite leg, all legs and whole body) is noted in concordance with the concentrations of sulphuric acid.

After each immersion in acid, the leg is washed with water and 2-3 minutes are waited until the next excitation. The immersion of leg into the solution of sulphuric acid should not exceed more than 90 seconds.

At the same frog, in right dorsal region is applied a piece of filter paper soaked into sulphuric acid 10%. It is noted the movements of right posterior leg for removing of acid solution from the excited region. After the immobilisation of the active leg, the region is stimulated again, exactly in the same place and the response is noted. Using the free leg, the frog makes movements for removing the irritant. (the law of reflex coordination).

Interpretation - the laws of medullary reflexes are valid only for exteroceptive (flexion) reflexes. The flexion reflexes are polysynaptic, namely the sensitive neuron comes into contact with several intercalar neurons (probably 6 - 10). The intervention of intercalar neurons explains some pecunirialities of flexion reflexes. A first peculiarity is the diffusion of impulses generated by exteroceptors in the spinal cord. The stronger the stimulation of exteroceptors, the more spread is the motor response. The flexion reflex lasts more than the time of stimulus application, due to the process of postdischarge occurred in the reverberatory circuits of the intercalar neurons.

2.13. Reflexes in medical diagnosis

The reflex centers are displayed metameric in spinal cord, that determines the segmental character of medullary reflexes. The existence of association ways makes as for the stimuli of high intensity, the response to be generalised. Every medullary reflex has the center localised in a certain metamere, by exploring the reflexes in clinics, it can be established the site/place of a medullary lesion.

Reflex testing is a standard, useful clinical procedure employed by physicians in search of neurological pathology. Damage to intervertebral disks, tumors, polyneuritis and many other conditions can be better understood with the aid of reflex studies. The diagnostic reflexes studied here are the ones most frequently employed by physicians.

Interpretation of reflex responses is often subjective and requires considerable experience on the part of diagnostician. Our purpose in performing the test here is not to diagnose, but rather to test and observe and to understand why a particular test is performed.

Clinically, reflexes are categorized as being either deep or superficial. The deep reflexes include all reflexes that are elicited by a sharp tap on an appropriate tendon or muscle. They are also called jerk, stretch, or myotatic reflexes. The receptors (spindles) for these reflexes are located in the muscle, not in the tendon. When the tendon is tapped, the muscle is stretched; stretching the muscle, in turn, activates the muscle spindle, which triggers the reflex response. Superficial reflexes are withdrawal reflexes elicited by noxious or tactile stimulation. They are also called cutaneous reflexes. Instead of percussion initiating these reflexes, the skin is stroked or scratched to induce a response.

Reflex aberrations

Abnormal responses to stimuli may be diminished (hyporeflexia) or exaggerated (hyperreflexia). Hyporeflexia may be due to malnutrition, neuronal lesions, aging, deliberate relaxation. Hyperreflexia is often accompanied by marked muscle tone due to the loss of inhibitory control by the motor cortex. Among other things, it may also be caused by strychnine poisoning. Pathological reflexes are reflex responses that occur in one or more muscles other
than the muscle where the stimulus originates. It is these three deviations that we will look for in performing these tests.

**Materials**: reflex hammer

**Reflexes of the arm and hand**

**Biceps reflex** is a deep reflex which causes flexion of the arm. It is elicited by holding the subject's elbow with the thumb pressed over the tendon of the biceps brachii. To produce the desired response, strike a sharp blow to the first digit of the thumb with the reflex hammer. If the reflex is absent or diminished, apply reinforcement by asking the subject to clench his/her teeth or squeeze his/her thigh with the other hand. Test both arms and record the degree of response in your notebook. This reflex functions through C5 and C6 spinal nerves.

**Triceps reflex** - this deep reflex causes extension of the arm in normal individuals. To demonstrate it, flex the arm at the elbow, holding the wrist. Strike the triceps brachii tendon above the elbow with the pointed end of the reflex hammer. Test both arm and record the degree of response. This reflex functions through G6 and C5 spinal nerves.

**Brachioradialis reflex** - in normal individuals this reflex manifests itself in flexion and pronation of the forearm and flexion of the fingers. To demonstrate this reflex, direct the subject to rest the on the thigh. Strike the forearm with the wide end of the reflex hammer cloth about 1 inchndtrtrnfrnrfrf above the end of the radius. The tendon that is stroke here is for the brachioradialis muscle of the arm. The reflex functions through the same spinal nerves (C5 and C6) as the biceps brachii reflex.

**Reflexes of the leg**

**Pattelar reflex** is a monosynaptic reflex known as knee reflex, jerk reflex or quadriceps reflex. To perform this test, the subject should be seated on the edge of a table with the leg suspended and somewhat flexed over the edge. To elicit the typical response, strike the patellar tendon, which is just below the kneecap. A phenomenon called clonus is sometimes seen when inducing the reflex. Clonus is characterised by a succession of jerklike contractions that follow the normal response and persist for a period of time. This condition is a manifestation of hyperreflexia and indicates damage within the central nervous system. This reflex function through L2, L3 and L4 spinal nerves.

**Achilles reflex** - it is also referred as ankle jerk. It is characterized by plantar flexion when the Achilles tendon is struck sharp blow. Stretching this tendon affects muscle spindles in the triceps surae, causing it to contract. To perform this test, grip the foot with the left hand. The reflex functions through S1 and S2 spinal nerves. Hyporeflexia here is often a sign of hypothyroidism.

**Plantar flexion ( Babinskfs sign)** - this reflex is the only one in this series that is of a superficial nature. The normal reaction to stroking the sole of the foot in an adult is plantar flexion. If dorsiflexion occurs, starting in the great toe and spreading to the other toes (Babinskfs sign) it may be assumed that tehere is myelin damage to fibers in the pyramidal tracts. Incidentally, dorsiflexion is normal in infants , especially if they are asleep. Babinskfs sign disappears in infants once myelinization of the nerve fibers is complete. This reflex functions S1 and S2 spinal nerves. Perform this test on the bottom of the foot of a subject, using a hard object as a key.

**2.14. Biofeedback**

Recently has been increased the interest in mind-body interactions. There are many processes in the body in which you exert voluntary control. For example, if you want a glass of water, you move your body and go through the motions to take out of glass, fill it with water and drink. You are consciously aware of the motions that are under your voluntary control. However,
once you start to swallow the drink of water, you are not usually aware of the regulatory processes which follow automatically (e.g. you secrete saliva, rhythmic constrictions in the esophagus move the water down the stomach, the stomach starts churning).

These processes are regulated by autonomic nervous system and do not require conscious control by the cerebral cortex. Muscle movement to obtain a drink of water involves some voluntary controls (wherein your brain and body interact in a loop between sensory reinforcement of movement and the brain) but there is usually no loop of feedback between consciousness and the involuntary actions regulated by the autonomic nervous system, e.g. actions of the gastrointestinal tract.

The autonomic nervous system has two regulatory divisions, which can affect the same organs or tissues but exert contrasting effects:

- **sympathetic nervous system** (SNS) - short term response to acute stress, "fight or flight" response
- **parasympathetic nervous system** - daily routine maintenance of homeostasis

Essentially, biofeedback completes the loop between autonomic functions and conscious awareness. Biofeedback training is a learning process whereby people exert conscious control over physiological processes controlled by the autonomic nervous system. Biofeedback instruments unobtrusively monitor physiological functions (e.g. heart rate) and provide feedback in real time. The equipment provides feedback using a signal that changes with the monitored variable. The person can then use the signal to enhance the desired response.

With biofeedback training, people have been able to regulate many processes: lower heart rate, lower blood pressure, control headaches and manage responses to stressful situations. For example, biofeedback training has been shown to be effective for controlling high blood pressure.

One training method consists of a "hand warming response" - that is, the biofeedback signal is associated with the temperature of the hands. What does "hand warming" have to do with high blood pressure? Well, BP is a result of cardiac output and peripheral resistance. Peripheral resistance is inverse proportional to the amount of blood flow to the periphery. Because blood is warmed in the body, when blood flow to the skin increases, the skin is warmer. Therefore, warmer hands signify increased blood flow that occurred when peripheral resistance and blood pressure decrease.

Biofeedback training has also been used to teach stress management techniques. In physiological terms, relaxation using biofeedback training teaches people to activate specific controls of the parasympathetic part of the autonomic nervous system, e.g. to lower heart rate. At the same time, biofeedback can be used to decrease activity of the SNS.

The **galvanic skin response** (GSR) or electrodermal activity is one variable traditionally associated with SNS activity. The GSR is affected by sweat gland activity and skin responses on the palmar-surface of the hand. Unlike the heart, the sweat glands are only activated by sympathetic activity. If the sympathetic branch of the autonomic nervous system is highly aroused, then sweat glands activity increases and consequently, so does GSR. Because of this association, the GSR is traditionally used as an index of SNS activity. When a person is relaxed, then the GSR should be low.

GSR has been used as a measure of emotional and sympathetic response. GSR responses are delayed 1-3 seconds. External factors, such as: temperature, humidity or internal factor, medication affect GSR measurements.

In this lesson the biofeedback signals will be plotted on the screen as a thermometer style bar chart that will rise and fall with changes in heart rate and GSR, allowing the subject to become conscious of his/her heart rate and arousal. (GSR). The subject will try to change the reading(s) without physical movements and should be able to see that the heart rate and level of arousal are independent.