BIOPAC Systems, Inc.
Registered to ISO 9001:2008
42 Aero Camino, Goleta, CA 93117
www.biopac.com

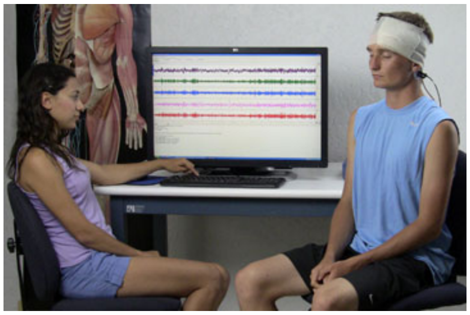
Biopac Student Lab® Lesson 3

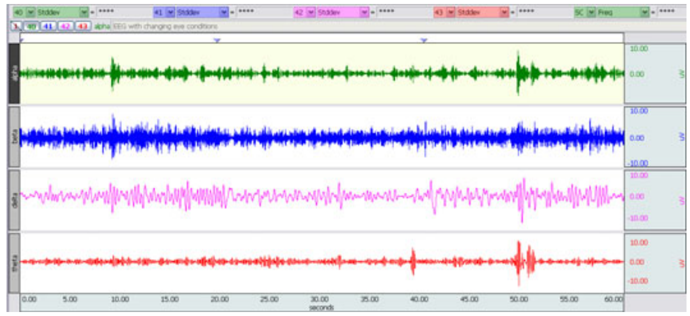
ELECTROENCEPHALOGRAPHY (EEG) I
Introduction

Rev. 08142013

Richard Pflanzer, Ph.D.
Associate Professor Emeritus
Indiana University School of Medicine
Purdue University School of Science

William McMullen
Vice President, BIOPAC Systems, Inc.





I. INTRODUCTION

The **brain** is encased by the **cranium**, bones of the skull which immediately cover and protect brain surfaces. A thin cover of skin, called the **scalp**, covers most of the cranium. 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 functionally 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 or legal sense,) absence of electrical activity in the human cerebral cortex signifies death.

Functions of the cerebral cortex include abstract thought, reasoning, voluntary and involuntary control of skeletal muscle, and the recognition and differentiation of somatic, visceral, and special sensory stimuli. Specific regions of the cerebral cortex process or generate various kinds of information. For example, the **occipital lobe** processes visual information while the **parietal lobe** processes somatosensory information such as cutaneous pain or temperature (Fig. 3.1).

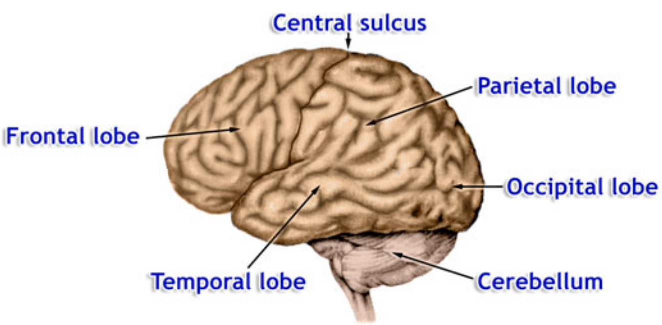


Fig. 3.1 Regions of the brain

The sensory information is relayed from the periphery through lower centers in the brain, and then the information is sent to various regions of the cerebral cortex. 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. The recording of the brain's activity obtained by using electrodes is called **electroencephalogram** or **EEG** (*electro* = electrical, *encephelo* = brain, *gram* = record).

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, one square millimeter of cortex has more than 100,000 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 the EEG. (For more information about waveforms, see "Waveform Concepts" in the BSL Tutorial.)

It is only when the input to a region is **synchronized** with electrical activity occurring at the same time that you begin to distinguish simple, periodic waveforms in an EEG.

In 1929, an Austrian physician named Hans Berger discovered that electrodes placed on the scalp could detect various patterns of electrical activity. After verifying that the recordings were indeed recording from the brain, and were not artifacts of muscle or scalp, scientists began to study these "brain waves." Today, the EEG is still a medically useful recording for brain function. In medical and basic research, the correlation of particular brain waves with sleep phases, emotional states, psychological profiles, and types of mental activities is ongoing.

Four simple periodic rhythms recorded in the EEG are **alpha**, **beta**, **delta**, and **theta**. These rhythms are identified by **frequency** (**Hz** or **cycles/sec**) (Table 3.1). The amplitudes recorded by scalp electrodes are in the range of microvolts (µV or 1/1,000,000 of a volt).

Table 3.1 Typical Frequencies of Synchronized Brainwaves

Rhythm	Typical Frequencies (Hz)
alpha	8-13
beta	13-30
delta	1-5
theta	4-8

Alpha

The four basic rhythms have been associated with various states. In general, the alpha 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 alpha 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 alpha waves than males
- alpha wave amplitudes are likely to be higher in “outgoing” subjects
- alpha wave amplitudes vary with a subject’s attention to mental tasks performed with the eyes closed

In general, amplitudes of alpha waves diminish when subjects open their eyes and are attentive to external stimuli although some subjects trained in relaxation techniques can maintain high alpha amplitudes even with their eyes open.

Beta

Beta rhythms 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. Notice that the amplitude of beta rhythms tends to be lower than for alpha rhythms. This does not mean that there is less electrical activity, rather which the “positive” and “negative” activities are starting to counterbalance so that the sum of the electrical activity is less. Thus, instead of getting the wave-like synchronized pattern of alpha waves, **desynchronization** or **alpha block** occurs. So, the beta wave 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

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 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 rhythms are highly variable within and between individuals.

Electrode positions

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

In today’s lesson, you will record an EEG using the bipolar method.