Electroencephalography I Laboratory

Electroencephalography I Laboratory

Introduction

Neurons in the brain can impact all aspects of human life including completing motor activities, performing mental thought, memories, and dreaming. The electroencephalogram (EEG) is a recording from the surface of the scalp generated by many biopotentials in the cerebrum of the brain. More specifically, it is a recording of the action potentials and the postsynaptic potentials of cortical cells. Since we are recording from the surface of the scalp, we are measuring potentials from many cells at the same time. The potentials of the neurons in the brain can vary as a function of the emotional, mental, or physiological state of the person. At first glance, EEG data may look like an unstructured, non-stationary, noisy signal. However, advanced signal processing techniques can be used to separate different components of the brain waves. These separate components can then be associated with different brain areas and functions. Current research focuses on discovering correlations between specific brain activity patterns to disease, emotional states, sleep phases, and mental health. In a clinical setting, EEG's are often used to diagnose neurological disorders such as epilepsy, monitor patient's consciousness level during surgical procedures, and to measure brain activity during sleep studies. In addition, it has also been shown that the EEG signal can be used as control inputs for other systems such as a brain computer interface albeit at low data rates. This could be useful in the case of spinal cord injury patients to restore function. In this lab, you will use the BioRadio to detect the electrical activity of neurons in the cerebral cortex and apply some simple analysis techniques to interpret the data.
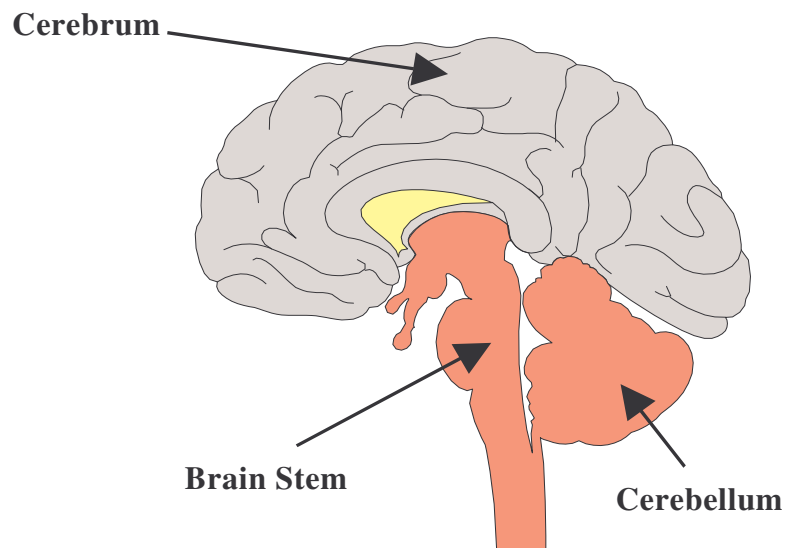

Figure 1: The human brain is comprised of three main regions.

Equipment required:
- CleveLabs Kit
- CleveLabs Course Software
- Seven (7) Gold cup electrodes
- Conductive Gel
- Gauze, cotton balls, and wipes
- Microsoft Excel®, MATLAB®, or LabVIEW™

Background

The Brain

The human brain is a part of the central nervous system and is comprised of more than 100 billion nerve cells. The neurons in the brain are connected to ascending and descending tracts of nerve fibers in the spinal cord. These tracts contain the afferent (sensory) and efferent (motor) nerves that communicate information between the brain and the rest of the body. The brain can be divided into three major sections known as the cerebrum, the cerebellum, and the brain stem (Fig 1). Various types of information in the form of nerve impulses are transmitted and processed in the cerebral cortex.   The cerebral cortex, which is the largest part of the brain, is organized in such a way that functionally similar neurons are found in localized regions, and these regions are illustrated in Fig 2.
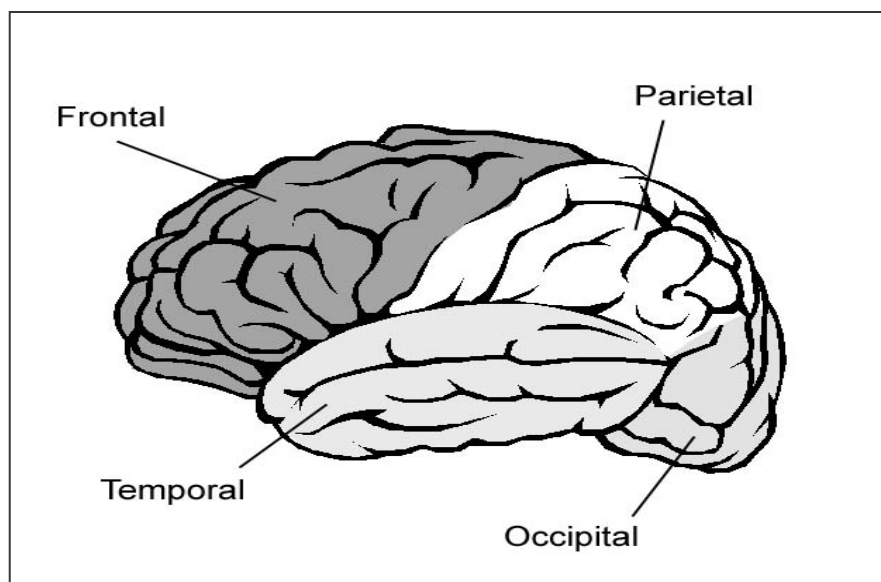

Figure 2: A diagram of the cerebral cortex, with the various lobes specialized for performing different functions.

For example, visual information is processed in the occipital lobe, motor planning is performed in the frontal lobe, and the temporal lobe is responsible for processing auditory information. Association of the different brain regions with specific functions was discovered by repeated experiments of monitoring the electrical activity of various brain regions while performing a specific task.
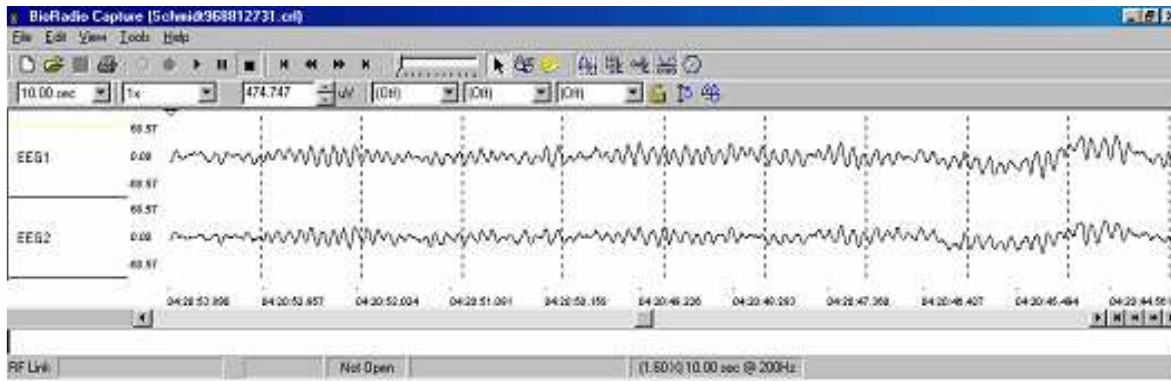
Figure 3: Sample of 2 channels of EEG with periods of alpha waves occurring.

Earlier, we alluded to the fact the EEG is produced by the postsynaptic currents of neurons in the brain. This is due to the geometry of the brain and the organization of neurons within the brain. The action potential refers to the signal propagating through the neuron, while the postsynaptic potential refers to the changes of transmembrane potential following the release of neurotransmitters at the end of a presynaptic axon, where the signal continues to another neuron.

The action potentials and synaptic potentials of individual neurons in the brain are much too small in amplitude to be detected by electrodes placed on the scalp. An EEG recording is rather a measure of the summation of the electrical signals produced by many neurons firing over a period of time. Depending on the state of the brain and the task being performed, the neurons may be firing synchronously or asynchronously. Neurons that are firing synchronously will have their potentials rise and fall at the same times. The EEG is a summation of these signals. Therefore, the peak values will add resulting in a relatively large signal. You can visualize this by thinking of adding two identical sine waves. The amplitude will double and the frequency of the signal will remain the same. Conversely, asynchronous firing neurons may or may not have signal peaks occur at the same time. This may or may not result in an overall smaller amplitude signal. Again, visualize the addition of two sine waves, but with different phases (i.e. a time shift). There may be an increase or decrease in amplitude depending on how the signals line up in time. One signal may even cancel another out.

EEG components

As stated earlier, the EEG signal can be broken down into different components. There are four frequency ranges that have been defined as primary components of the EEG: α (alpha), β (beta), Δ (delta), and θ (theta) waves. The frequencies and typical amplitudes of these components are shown in the table below.

Rhythm	Typical Frequencies (Hz)	Typical Amplitude (uV)
α	8 - 13	2-100
β	13 - 22	5-10
Δ	0.5 - 4	20-100
θ	4 - 8	10

Table 1 The typical frequencies and amplitudes of the different brainwave components are listed.

Alpha waves are generally found in the EEG when the individual is awake in a quiet, resting state with their eyes closed. The alpha wave can be detected primarily from the occipital lobe, but also from the parietal and frontal regions of the cerebral cortex. During sleep, however, the alpha waves disappear.

Beta waves are recorded from the parietal and frontal lobes. They appear when the individual performs some specific type of mental activity or are attentive to an external stimulus. They are lower in amplitude than the alpha rhythms, but this is not due to there being less electrical activity. Instead, desynchronization, also known as alpha block, occurs, reducing the amplitude of the net signal recorded from the scalp. As mentioned previously, non-synchronized potentials tend to cancel each other, resulting in a lower amplitude signal.

Theta waves occur mainly in the parietal and temporal regions. These occur sometimes during emotional stress and often in degenerative brain states. Delta waves are the very low frequency components of an EEG. Deep sleep and certain brain diseases give rise to delta waves.

EEG Electrode Placement

A method called the 10-20 system has been developed for placement of electrodes on the scalp during EEG recordings.   The 10 and 20 in the name refer to the percent distances that the electrodes are from each other in proportion to the size of the head. The 10-20 system relates the locations on the scalp to the locations of the cerebral cortex. The electrode locations used in the 10-20 system are indicated with a letter followed by a number. The letters that are used include F, T, C, P, and O. These letters correspond to frontal, temporal, central, parietal, and occipital, respectively. These are all lobes of the brain except for the central location.   The number in the

indicated position corresponds to the left or right side of the head. Even numbers are located on the right hemisphere while odd numbers are on the left. Some letters are followed by a Z instead of a number. The Z indicates the midline of the head. The following diagram illustrates these standard electrode positions:
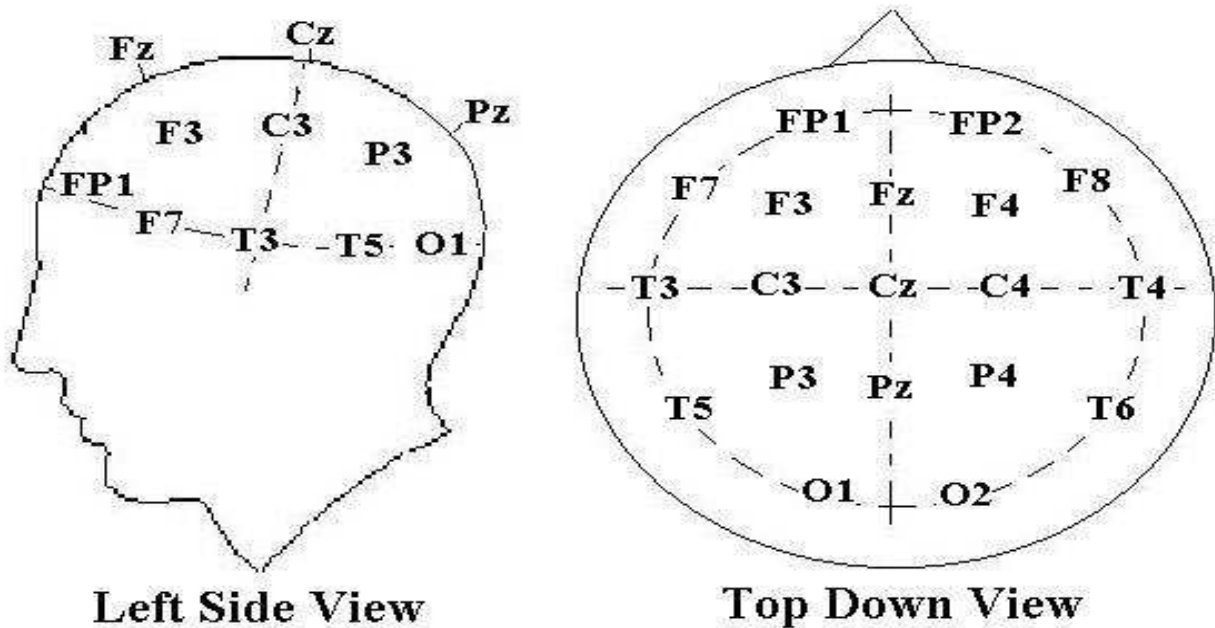

Figure 4: The 10-20 system of electrode placement.

Noise

Several sources of noise and artifact can interfere with accurately recording the EEG signal. One of the most common artifacts is an eye blink which creates spikes in the EEG. These spikes can sometimes be difficult to distinguish from those due to an epileptic attack. When the eye blinks, the eyelids act as a sliding potential source. Other sources of noise in include electromyographic (EMG) activity from muscles near the recording electrodes, such as muscles of the face and neck, and eye movements (EOG). Several techniques exist for removing the artifacts generated by EMG, EOG, and blinking. These techniques include filtering the data, performing correction on the data, or just completely throwing out any data with artifact. In order to minimize noise for this laboratory, the subject should relax their face and neck muscles and keep their eyes relatively still while recording EEG data.

Technology

Before computers became mainstream equipment for data recording, perhaps some 20 years ago, EEG was recorded by an old-fashioned pen-based strip chart, where a pen would move vertically depending on the amplitude of the detected signal while a long sheet of paper continuously moved under it. This of course was replaced by computer (digital) acquisition, which made it much easier for data archiving and analysis. Today, there are many commercial software packages available specifically designed for EEG analysis. It is important to note that EEG

Electroencephalography I Laboratory

studies typically last anywhere from a few hours to a few days. Obviously, this results in massive amounts of data that have to be stored and analyzed. Researchers are finding ways to implement automated data reduction and automated extraction of relevant information to increase efficiency.

Experimental Methods

Experimental Setup

During this laboratory session you will record four channels of EEG. Two channels will be recorded from the frontal region and two channels will be recorded from the occipital region. You should view the setup movie included with the CleveLabs software before beginning the experimental setup for this laboratory session.
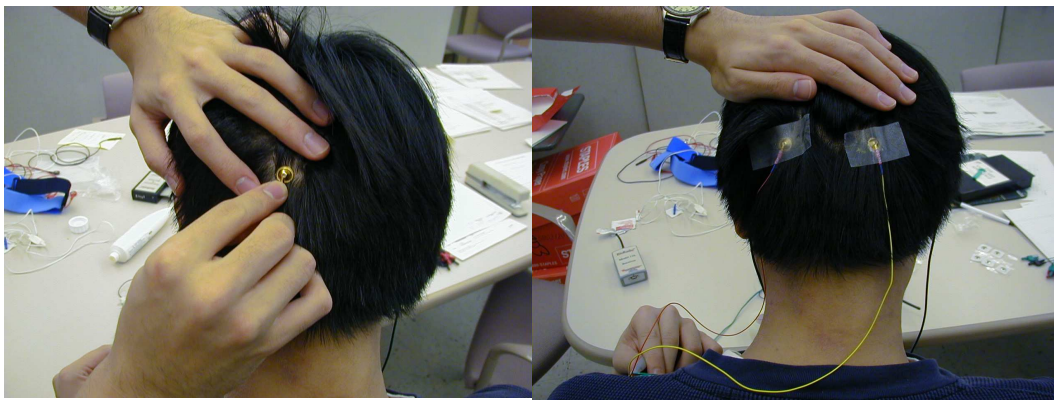

Figure 5: Two of the six gold cup electrodes will be placed at O1 and O2 to monitor EEG.

1. If possible, the subject for this laboratory should be a person with shorter hair. The subject also should have their scalp free of any types of hair gel. You will need seven gold cup electrodes for this laboratory. Gold cup electrodes will be placed at locations O1, O2, Fp1, and Fp2 (Fig 4) to measure EEG, on each mastoid as references, and at FpZ (middle of the forehead) for the ground. The mastoid processes (A1 and A2) are the bony structures that you can feel behind the ears (Fig 6). Before applying electrodes to the subject it is first important to properly prepare and clean the electrode sites. If needed, refer to previous labs for information on cleaning and preparing electrode sites.
2. Now the gold cup electrodes can be attached. Generously fill a gold cup electrode with the provided conductive gel allowing some gel to fill over the top of the cup. Squeeze some of the conductive gel onto a gauze pad as well. Push the electrode into the gel on the gauze pad and then gently push aside the hair and place the electrode on the back of the subject's head at position O1. Repeat for the other gold cup electrode at locations. The electrode placements for O1 and O2 are illustrated in Fig 5.
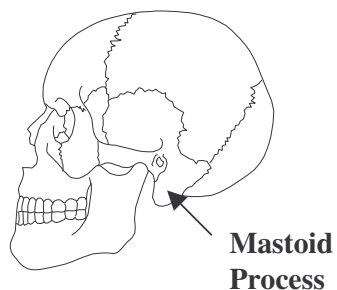
Electroencephalography I Laboratory

Figure 6: The mastoid processes are the bony structures located behind the ears.

3. Connect gold cup leads and jumpers to channel inputs 1, 2, 3, 4, and the ground using the picture below as a reference (Fig 7). The left side view of the head is symmetrical to the right side view as seen in the top down view.
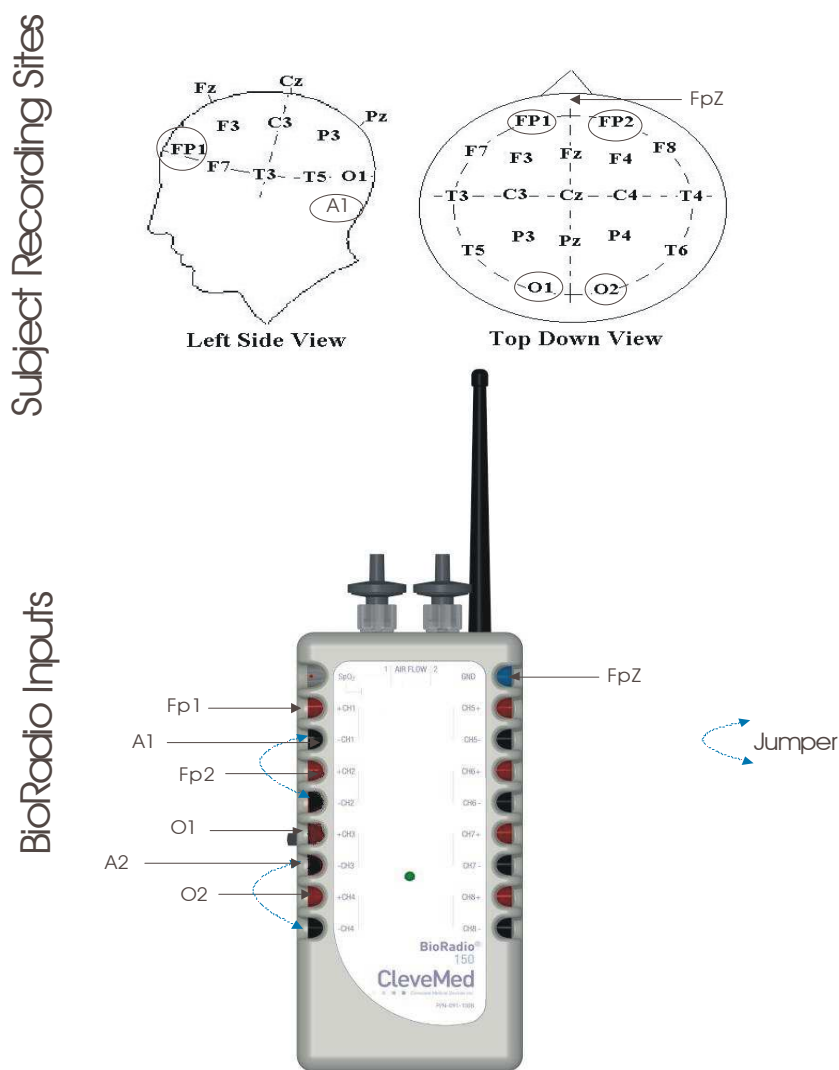

Figure 7: Laboratory EEGI Setup

Electroencephalography I Laboratory

Procedure and Data Collection

1. Run the CleveLabs Course software. Log in and select the "Electroencephalography I" laboratory session under the Basic Physiology subheading and click on the "Begin Lab" button.

2. Turn the BioRadio ON.

3. Your BioRadio should be programmed to the "LabEEGI" configuration.

4. Click on the EEG data Tab and then on the green "Start" button.

5. You should begin to see four channels of EEG scrolling across the screen. Set the time scale to show a 2 second window of data. Click on "Screen Capture" to capture a picture of this to your report. This may not look like EEG yet because you are not filtering out high frequency noise that may be contaminating the signal such as 60Hz noise.

6. Now click on the Spectral Analysis Tab. Click on the time plot tab and set the time scale on the time domain plot to be 1 second. Set the channel to process to channel 1.

7. Instruct the subject to look at the screen. Under filter parameters, set the switch to filtered data, filter type to bandpass, the high pass cutoff to 1Hz and the low pass filter to 20Hz and set the filter order to 4.

8. Instruct the subject to begin blinking rapidly and note what happens to the EEG signal. Capture a screen shot of this. Also, save approximately 10 seconds of this data to a file named "blink". About half the time should be blinking and half the time not blinking.

9. Instruct the subject to begin to chew and note what happens to the EEG signal. Capture a screen shot of this. Also save approximately 10 seconds of this data to a file named "chew". About half the time should be chewing and half the time not chewing.

10. Set the channel to process to be channel 1. After a few seconds instruct the subject to close their eyes and relax. You are attempting to record alpha waves from the subject (8-13Hz waves). You should see these waves show up when the subject closes their eyes and relaxes.   You should use a 4th order band-pass filter between 1 and 20 Hz.

11. Repeat step 10 with the "channel to process" set to 2, 3, and 4. Find the channel that gives the best alpha waves. You should already have some idea what this should be from the text. Once you find the best channel, report a screen shot of the EEG signal when the subject's eyes are open and when they are closed.

12. Do not change the parameters, but now click on the frequency domain plot tab. Examine what the estimated peak frequency is when the subject's eyes are open and when they are closed. When they are open, the estimated peak frequency should be fairly random, however, when they are closed, this frequency should remain within a certain range. Record this range, as you will need it for the next step.

13. Save approximately 30 seconds of data to file while the subject's eyes are opened. Name the data file "eyesopen".

14. Save approximately 30 seconds of data to file while the subject's eyes are closed and they are relaxed. Name the data file "eyesclosed".

Data Analysis

1. Using the post processing toolbox, MATLAB, or LabVIEW, open the data file named "eyesopen". Filter the data with appropriate filter settings to illustrate beta activity.

2. Using the post processing toolbox, MATLAB, or LabVIEW, open the data file named "eyesclosed". Filter the data with appropriate filter settings to illustrate alpha activity.

3. Using the post processing toolbox, MATLAB, or LabVIEW, open the data file named "blink". Determine the frequency component of the blink noise and try to remove it from the EEG signal.

4. Using the post processing toolbox, MATLAB, or LabVIEW, open the data file named "chew". Determine the frequency component of the chew noise and try to remove it from the EEG signal.

Discussion Questions

1. Explain sources of noise that you saw in the experiment. Also, suggest some methods for eliminating the sources of noise, and what problems may occur with those methods. Some hospitals have programs for automated EEG analysis to detect seizures or spiking activity that occur during data acquisition. How might a noisy recording affect these automated programs?

2. Why are gold cup electrodes used to record EEG instead of the snap electrodes? If a more detailed and localized EEG reading is desired, explore some other options for electrode placement.

© 2006 Cleveland Medical Devices Inc., Cleveland, OH.   9

Property of Cleveland Medical Devices. Copying and distribution prohibited.
CleveLabs Laboratory Course System Version 6.0

3. Where would you place gold cup electrodes on the head to measure alpha waves? Beta waves? Theta waves? Delta waves?

4. The beta rhythm typically ranges between 14-30 Hz. What particular source(s) of noise needs to be considered when analyzing the beta rhythm?

5. For each of your four saved data files including eyes opened, eyes closed, chew, and blink, what were the maximum frequency components of each activity? Were you able to successfully filter chewing and blinking from the EEG signal? If you were not able to describe why.

6. Using Matlab, create a program to filter your saved data into alpha and beta bands. Measure the energy of the alpha rhythm vs. time during the whole recording for channel 1 of the first experiment. Do the same for the beta rhythm. How do these energy measurements correlate with the eyes open/eyes closed states?

7. Use MATLAB with one of your data files to show that even though a differential recording was performed, 60 Hz noise can still be present in a recording. Use the data file from the first experiment.

8. There are two mechanisms responsible for creating the EEG signal. Both action potentials and post-synaptic potentials create the EEG. Explain the difference between these two mechanisms. Which of these is a graded signal and why?

© 2006 Cleveland Medical Devices Inc., Cleveland, OH.

10

Property of Cleveland Medical Devices. Copying and distribution prohibited.
CleveLabs Laboratory Course System Version 6.0

References

1. Guyton and Hall. <u>Textbook of Medical Physiology</u>, 9th Edition, Saunders, Philadelphia, 1996.

2. Kandel ER, Schwartz JH, Jessel, TM. Essentials of Neuroscience and Behavior.1995.

3. Kooi, Kenneth A. Fundamentals of Electroencephalography, Harper & Row, Hagerstown, MD. 2nd Ed. 1978.