Teacher’s Guide

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Hands-on Physiology Lessons

11 tutorial-style lessons allow students to record data from their own bodies

GETTING STARTED

- Setup Guide — booklet in shipping box; also available on CD and installed to C:\Program Files\Biopac Science Lab\User Support
- Quick Guide — available under Help menu or in User Support
- MP40 Hardware Guide — available under Help menu or in User Support

LESSON FEATURES

- On-screen commands prompt students throughout the lesson.
  
  ![Sample prompts and lesson buttons](image)

- Video clips and downloadable sample data files provide additional insight into the use of the system.
  
  - Video clips are under the Help menu
  - Videos are installed to C:\Program Files\Biopac Science Lab\User Support\Videos

- Extremely easy to set up and record data.
- Event markers can be added throughout the recording.
- The system includes example data files.
- Active learning options—students can design and record a new experiment to test or verify the scientific principle(s) covered in the Biopac Science Lab recording and analysis segments. The lesson software is used to record new data segments to fit the student’s protocol.
- Student prep and distance learning tools available in the software and online.
- Lessons written by experienced science teachers support national curriculum standards.
- Data Reports are installed with the software at C:\Program Files\Biopac Science Lab\User Support\Data Reports

Lesson 1 EMG I Muscle
Lesson 2 EMG II Muscle
Lesson 3 ECG I Heart
Lesson 4 ECG II Heart
Lesson 5 EEG I Brain
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Lesson 8 EOG Eyes
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Lesson 10 Aerobic Exercise
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Lesson 12 Respiration
ABOUT ELECTRODES

**ELECTRODE OVERVIEW**

**Attaching Disposable Electrodes**

- For optimal electrode response, place electrodes on the skin at least 5 minutes before starting to record data.

**Connecting Electrode Leads**

Each lead set has three pinch leads designed to snap directly onto standard disposable electrodes (such as the EL500 series electrodes). Each pinch lead is 1 meter long. This is the general-purpose electrode cable used for almost all applications requiring the use of electrodes. These cables are used to connect the disposable electrodes that are placed on the surface of the skin to the MP40 unit. Depending on where the electrodes are placed, you can use them to measure muscle contraction, heartbeats, or even brainwaves.

- **Red** – positive
- **White** – Negative
- **Black** – Ground

- Each pinch connector on the end of the electrode cable needs to be attached to a specific electrode. The electrode cables are each a different color. Follow the color code above to ensure that each cable is connected to the proper electrode.

- The pinch connectors work like a small clothespin, but will only latch onto the snap of the electrode from one side of the connector.

**Removing Electrodes**

- Unclip the electrode leads and peel off the electrodes.
- Throw out the electrodes (BIOPAC electrodes are not reusable).

*Use soap and water to wash the electrode gel residue from the skin. It is quite normal for the electrodes to leave a slight ring on the skin for a few hours.*

**Using Electrodes**

**About Electrodes**

The purpose of an electrode is to act as a “connector” between the Subject’s skin (where electrical signals are easiest to detect) and the MP40 acquisition unit (via the 40EL lead cable). If an electrode makes good contact with the skin, the signals that are generated will be relatively accurate.

Electrodes are very simple devices that consist of a small piece of metal designed to make indirect contact with the skin and a larger adhesive plastic disk. Each electrode is about 1 inch (2.5 cm) in diameter, and is sticky on one side so it will adhere to your skin.
If you look closely at the electrode, you can see that there is a small piece of plastic mesh filled with a bluish gel. Since gel conducts electricity (better than your skin, in fact) and is more flexible than the metal part of the electrode, your skin can flex and change shape somewhat without losing the electrical connection with the metal part of the electrode.

BIOPAC disposable electrodes are standard disposable electrodes and are widely used in clinical, research, and teaching applications. These electrodes come in strips of ten, and you should not remove an electrode from the backing until you are ready to use it.

The following directions will help you get good data from the electrodes by explaining how electrodes work and how to attach the electrodes and electrode leads to obtain the best signal.

**Electrode placement**

There are two basic methods of electrode placement: monopolar and bipolar.

- **In a monopolar recording,** an active electrode is placed over the region of interest and a “reference” electrode is attached to a more distant part of the body.

- **In a bipolar recording,** the voltage difference between two electrodes, placed over the regions of interest, is measured with respect to the third “reference” electrode. Leads I, II, and III are standard bipolar electrode configurations. The **standard bipolar limb leads** are:
  
  **lead I** = right arm (-), left arm (+)
  
  **lead II** = right arm (-), left leg (+)
  
  **lead III** = left arm (-), left leg (+)

**Preparing the Electrode Site**

If signals are erratic, one way you can improve electrode connections is to gently rub the area where the electrode is to be placed. This is known as **abrad ing** the skin, and removes a thin layer of dead skin from the surface of the skin. Since dead skin doesn’t conduct electricity very well, removing it improves the connection between the electrode and the skin. The skin site can be lightly abraded with a clean dry cloth.

**Attaching electrodes**

To attach an electrode, peel the electrode from its backing and place it on the area indicated in the lesson. Once in place, press down firmly on the electrode with two fingers and rock the electrode back and forth for a few seconds. This will ensure that it is adhering to the skin as much as possible.

- To help insure that the electrode will make good electrical contact with the skin, you may want to squeeze a drop or two of **electrode gel** (BIOPAC GEL1 or GEL100) onto either the surface of the skin or onto the electrode, without allowing any to get on the adhesive.
Connecting the Electrode Lead

Each electrode lead cable is a different color and each pinch connector on the end of the cable needs to be attached to a specific electrode. Note that the connector is polarized and needs to be clipped on such that the metal extensions inside the clip are on the down side to make surface contact with the electrode. The pinch connectors work like a small clothespin, but will only latch onto the snap of the electrode from one side of the connector. You should follow the figure provided in the lesson to ensure that you connect each lead cable to the proper electrode.

Reducing Electrode “Noise”

If an electrode does not adhere well to the skin, the signal plotted on the screen may appear “fuzzy.” This is referred to as “noise,” and although it always exists to some degree, it is best to reduce noise as much as possible. Electrodes have no moving parts, so there is nothing you have to do to get an electrode to “work” but there are several things you can do to reduce noise when electrodes are connected:

- Place the electrodes where there is the least amount of hair and/or choose the subject with the least amount of hair. A common problem is that something on the surface of the skin is interfering with the electrode contact. If there is too much hair (for instance) between the outer layer of skin and the electrode, the electrical activity taking place below the surface of the skin may not be detected.
- Make sure that everything is connected properly.
- Attach the electrodes a few minutes before you are going to use them. The best results are achieved by putting the electrodes in place about five minutes before you begin recording data. This gives the electrodes time to establish contact with the surface of the skin.
- Position the electrode lead cables such that they are not pulling on the electrodes. Connect the electrode cable clip (where the cable meets the three individual colored wires) to a convenient location (can be on the Subject’s clothes). This will relieve cable strain.
- The Subject should not be in contact with nearby metal objects (faucets, pipes, etc.), and should remove any wrist or ankle bracelets.

Removing Electrodes

Once you have completed a lesson, disconnect the electrode cable pinch connectors, peel the electrode off the skin, and dispose of the electrode (BIOPAC electrodes are not reusable). Wash the electrode gel residue from the skin, using soap and water. The electrodes may leave a slight ring on the skin for a few hours. This is normal, and does not indicate that anything is wrong.
The Body Electric

Generally, people think of electricity flowing through bodies as an unusual occurrence. For instance, they may think of rather unique animals, such as electric eels, or of rare events such as being struck by lightning. What most people do not realize is that electricity is part of everything their body does...from thinking to doing aerobics—even sleeping.

In fact, physiology and electricity share a common history, with some of the pioneering work in each field being done in the late 1700's by Count Alessandro Giuseppe Antonio Anastasio Volta and Luigi Galvani. Count Volta, among other things, invented the battery and had a unit of electrical measurement named in his honor (the Volt). These early researchers studied “animal electricity” and were among the first to realize that applying an electrical signal to an isolated animal muscle caused it to twitch. Even today, many classrooms use procedures similar to Count Volta's to demonstrate how muscles can be electrically stimulated.

Over the next few weeks, you will likely see how your body generates electricity while doing specific things like flexing a muscle or how a beating heart produces a recognizable electric “signature.” Many of the lessons covered in this manual measure electrical signals originating in the body. In order to fully understand what an electrical signal is requires a basic understanding of the physics of electricity, which properly establishes the concept of voltages, and is too much material to present here. All you really need to know is that electricity is always flowing in your body, and it flows from parts of your body that are negatively charged to parts of your body that are positively charged.

As this electricity is flowing, sensors can “tap in” to this electrical activity and monitor it. The volt is a unit of measure of the electrical activity at any instant of time. When we talk about an electrical signal (or just signal) we are talking about how the voltage changes over time.

The body’s electrical signals are detected with transducers and electrodes and sent to the MP40 acquisition unit computer via a cable. The electrical signals can be very minute—with amplitudes sometimes in the microVolt (1/1,000,000 of a volt) range—so the MP40 amplifies these signals, filters out unwanted electrical noise or interfering signals, and converts these signals to a set of numbers that the computer can read. The Biopac Science Lab then plots these numbers as waveforms on the computer.

The body contains fluids with ions that allow for electric conduction. This makes it possible to use electrodes on the surface of the skin to detect electrical activity in and around the heart and use an electrocardiograph to record the activity. Conveniently, the legs and arms act as simple extensions of points in the torso, allowing the recording and ground electrodes to be placed on the wrists and ankles. The electrocardiogram is a record of the overall spread of electric current through the heart as a function of time in the cardiac cycle. The direction of polarity (+ or -) of the recorded waveforms depends upon the location of the recording electrodes on the surface of the body and whether the electrical activity during the cardiac cycle is coming toward or going away from the surface electrode. In general, as a wave of depolarization approaches a positive electrode, a positive voltage is seen by that electrode. If the wave of depolarization is traveling toward a negative electrode, a negative voltage will be seen.

The term “lead” is defined as a spatial arrangement of two recording electrodes on the body. One lead is labeled + and the other -. The electrode placements define the recording direction of the lead, which is called the lead axis or angle. The axis is determined by the direction when going from the negative to positive electrode. The electrocardiograph computes the voltage difference (magnitude) between the positive and negative electrodes and displays the changes in voltage difference with time.
Waveforms

The BIOPAC software takes the signal input and plots it as a waveform on the computer screen. The waveform of the signal can be either a direct reflection of the electrical signal from the MP unit channel (amplitude is in Volts) or a different waveform which is based on the signal coming into the MP unit. For example, the electrical signal into the MP unit may be an ECG signal, but the software may convert this to a Beats Per Minute (BPM) waveform.

When you use any BIOPAC software, it is important to at least have a basic understanding of what the waveforms on the screen represent. The waveform below is a plot of Amplitude versus Time. As shown, the earliest data appears at the left edge of the screen, and the most recent data at the right edge.

- **Amplitude** is determined by the MP unit hardware according to what it senses at one of its inputs, which is actually the signal output from a transducer, set of electrodes, or other device. The units are shown in the vertical scale region; the unit for this example is Volts.

- **Time** is the time from the start of the recording, which is to say that when the recording begins it does so at what the software considers time 0. The units of time are shown in the horizontal scale region; the unit for this example is milliseconds (1/1,000 of a second).

Diving a little deeper into what a waveform represents, you are actually looking at data points that have been connected together by straight lines.

These data points are established by the BIOPAC system hardware by sampling the signal inputs at consistent time intervals. These data points can also be referred to as points, samples, or data.

The time interval is established by the sample rate of the BIOPAC software, which is the number of data points the hardware will collect in a unit of time (normally seconds or minutes). The BIOPAC software stores these amplitude values as a string of numbers. Since the sample rate of the data is also stored, the software can reconstruct the waveform.

Since BIOPAC software can simultaneously record signals from up to four (education units) or more inputs, there may often be more than one waveform on the screen. It is worth noting that the BIOPAC software always uses the same sample rate for all channels on the screen, so the horizontal time scale shown applies to all channels, but each channel has its own vertical scale. A channel’s vertical scale units can be in Volts, milliVolts, degrees F, beats per minute, etc.

A baseline is a reference point for the height or depth (“amplitude”) of a waveform.

- Amplitude values above the baseline appear as a “hill” or “peak” and are considered positive (+).

- Amplitude values below the baseline appear as a “trough” or “valley” and are considered negative (−).
Lesson 1 — EMG 1  Electromyography: Motor Unit Recruitment

EMG 1 investigates the properties of skeletal muscle. Students record the EMG data associated with the maximum clench strength for their dominant hand and non-dominant hand. The system records and displays both the raw and integrated EMG signals. Students compare clench strength between their two arms and listen to the sound of their EMG. It is also possible for students to perform a cross-group analysis.

EXPERIMENTAL OBJECTIVES

- To record maximum clench strength for right and left hands.
- To observe, record, and correlate motor unit recruitment with increased power of skeletal muscle contraction
- Optional: To listen to EMG “sounds” and correlate sound intensity with motor unit recruitment.

TASKS PERFORMED BY THE STUDENT

- Record EMG from the dominant and non-dominant forearms.
- Clench fist four times, squeezing harder each time to reach maximum clench strength with the fourth clench.
- Optional: Listen to the sound of their EMG.

KEY FEATURES

- Raw and Integrated EMG signals can be overlapped for easy interpretation of the data.
- Comparison between the dominant and non-dominant arms.
- The students listen to the sound of motor unit recruitment.

MATERIALS

- Biopac Science Lab intro system (uses six electrodes per subject)
- Optional: Headphones (40HP) to listen to the EMG signal
Lesson 2 — EMG 2 Electromyography: Mechanical Work

EMG 2 examines motor unit recruitment and skeletal muscle fatigue. Students lift hand weights to demonstrate the use of skeletal muscle and record EMG while inducing muscle fatigue. Students see the level of motor unit recruitment associated with the amount of applied force.

EXPERIMENTAL OBJECTIVES

- To record EMG response to increased weights lifted by dominant and non-dominant arms.
- To compare differences between male and female students.
- To observe, record, and correlate motor unit recruitment with increased mechanical work by skeletal muscle.
- To record EMG and Integrated EMG when inducing fatigue.
- Optional: To listen to EMG “sounds” and correlate sound intensity with motor unit recruitment.

TASKS PERFORMED BY THE STUDENT

- Lift weight (bicep curl) and hold for 2 seconds.
- Repeat cycles of weight lifting; add weight for each cycle until the Subject is lifting the maximum weight.
- Lift the maximum weight to 45 degrees and hold it until the onset of fatigue.
- Repeat the sequence for the non-dominant arm.
- Optional: Listen to the sound of their EMG.

KEY FEATURES

- Classic, clinical grid markings available for quick and easy evaluations.
- Raw and Integrated EMG signals can be overlapped for easy interpretation of the data.
- The students compare their dominant and non-dominant arms.
- The force values are scaled to kilograms.
- A clear demonstration of mechanical work.

MATERIALS

- Biopac Science Lab intro system (uses six electrodes per subject)
- Weight set (i.e., 5-10-15-20 kg dumbbells) — Subjects must lift the same weights for valid comparisons
- String to standardize distance lifted
- Ruler to measure distance lifted
- Optional: Headphones (40HP) to listen to the EMG signal
ECG 1 introduces the electrocardiograph and the recording of the heart’s electrical signal. Students learn about Lead II ECG recording and the components of the ECG complex. They also learn to correlate the electrical events of the ECG (P, Q, R, S & T components) with the mechanical events of the cardiac cycle. After performing a number of tasks designed to promote changes in the ECG complex, students analyze their own ECG recording.

**EXPERIMENTAL OBJECTIVES**

- To become familiar with the electrocardiograph as a primary tool for evaluating electrical events within the heart.
- To observe rate and rhythm changes in the ECG associated with body position and breathing.

**TASKS PERFORMED BY THE STUDENT**

- Lie down and relax.
- Take five deep breaths.
- Perform a physical exercise to increase heart rate.
- Relax while heart rate returns to normal.

**KEY FEATURES**

- Rate and ECG signals can be overlapped for easy interpretation of the data.
- The baseline can be adjusted for precise analysis and printing.
- Zoom in for a closer look at an individual ECG complex.
- See how the ECG complex changes under different conditions.
- Convenient electrode placement (wrists and ankles).

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**MATERIALS**

- Biopac Science Lab intro system (uses three electrodes per subject)
- Cot or lab pillow
ECG 2 explains Einthoven’s triangle. Students record Leads I and III while performing a number of tasks designed to change the rhythm of the heart. They then analyze the data and estimate the mean QRS axis and potential.

**EXPERIMENTAL OBJECTIVES**

- To record ECG from Leads I and III in the following conditions: lying down, sitting up, and breathing deeply while sitting.
- To compare the direction of the QRS complex (+ or –) with the direction of the lead axis.
- To estimate the mean ventricular potential.
- To estimate the mean electrical axis of the QRS complex.

**TASKS PERFORMED BY THE STUDENT**

- Record ECG using bipolar Leads I and III.
- Lie down and relax.
- Sit and relax.
- Breathe in and out once in each position.

**KEY FEATURES**

- The software makes it very easy for the student to compute the ECG vectors.
- Classic, clinical grid markings available for quick and easy evaluations.
- See how the ECG complex changes under different conditions.
- Students place markers for each component (P, Q, R, S, and T).
Lesson 5 — EEG 1  Electroencephalography: Brain Rhythms

EEG 1 introduces electroencephalographic recording techniques. Students record EEG from the occipital lobe while performing a number of different tasks to demonstrate how the brain’s electrical activity varies depending on the task. The software filters the raw EEG signal to separate and display alpha, beta, delta, and theta rhythms.

EXPERIMENTAL OBJECTIVES
- To record an EEG from an awake, resting subject with eyes open and eyes closed.
- To identify and examine alpha, beta, delta, and theta components of the EEG complex.
- To compare differences between male and female students.

TASKS PERFORMED BY THE STUDENT
- Record EEG from the occipital lobe.
- Record EEG from a relaxed subject with their eyes closed, eyes open, and eyes closed again.

KEY FEATURES
- Alpha, beta, delta and theta wave components are automatically filtered and displayed.
- View the different EEG wave components.
- Overlap the EEG wave components for a better view of the data.

MATERIALS
- Biopac Science Lab intro system (uses three electrodes per subject)
- Optional: Lycra® swim cap (such as Speedo® brand) or supportive wrap (such as 3M Coban™ self-adherent support wrap) to press the electrodes against the head for improved contact.
In EEG 2, students will discover how the brain constantly receives sensory input and integrates the information before processing it. Students record EEG data from the occipital lobe while performing a number of tasks. The system records and displays the raw EEG together with the alpha wave and alpha-RMS activity. Students compare baseline EEG with the data recorded during the different tasks.

**EXPERIMENTAL OBJECTIVES**

- To record an EEG from an awake, resting subject under the following conditions:
  - relaxed with eyes closed;
  - performing mental arithmetic with eyes closed;
  - hyperventilating (breathing quickly and deeply); and
  - relaxed with eyes open.
- To examine differences in the level of alpha rhythm activity during mental arithmetic and hyperventilation, compared to the control condition of eyes closed and relaxed.

**TASKS PERFORMED BY THE STUDENT**

- Record EEG data from the occipital lobe.
- Lie down and relax with eyes closed.
- Perform mental math problem with eyes closed.
- Hyperventilate for two minutes.
- Recover from hyperventilation with eyes open.

**KEY FEATURES**

- Alpha wave activity and alpha-RMS waveforms are automatically filtered and displayed.
- Overlap the EEG wave components, raw and alpha, for a better view of the data.
Lesson 8 — EOG 1 *Electrooculogram*

In EOG 1, students record horizontal eye movement and observe eye fixation and tracking. Students perform a number of tasks that allow them to record the duration of saccades and fixation. Students also record spatial position of eye movements.

**EXPERIMENTAL OBJECTIVES**

- Record EOG on the horizontal plane and compare eye movements under the following conditions: pendulum tracking, pendulum simulation, reading silently, reading aloud, and reading challenging material.
- Measure duration of saccades and fixation during reading.
- *Optional:* explore microsaccadic eye movement.

**TASKS PERFORMED BY THE STUDENT**

- Record horizontal EOG.
- Track pendulum movement with eyes only, trying not to move head or blink.
- Simulate pendulum movement (decreasing swing cycles) with eyes only.
- Read Passage 1 (easily understandable material) silently (to self) for 20 seconds.
- Read Passage 2 (challenging material) silently (to self) for 20 seconds.
- Read Passage 1 aloud.
- *Optional:* Focus on an on-screen guide; position of guide represents point of focus.

**KEY FEATURES**

- Tools for zooming in to see the saccades.
- Great introduction to EOG.

**MATERIALS**

- **Biopac Science Lab** intro system (uses three electrodes per subject)
- Pendulum (metronome may be used; signal pattern will be constant vs. diminishing)
- Passages for reading:
  - Passage 1 — easily understandable (i.e., entertainment article)
  - Passage 2 — challenging (i.e., scientific article)
Lesson 9 — Biofeedback Influencing Autonomic Tone

The Biofeedback lesson explores the concept of biofeedback training and its effect on autonomic control of heart rate. An onscreen, thermometer-style heart rate display rises and falls with changes in heart rate, allowing students to become conscious of their heart rates. The Subject will try to influence the reading without physical movements.

EXPERIMENTAL OBJECTIVES

- Introduce the concept of biofeedback as a technique to alter autonomic tone.
- Measure changes in autonomic tone via heart rate.

TASKS PERFORMED BY THE STUDENT

- Record ECG and heart rate.
- Sit and relax with eyes open, facing away from the screen to establish baseline heart rate and ECG.
- Watch monitor and mentally try to voluntarily increase parasympathetic tone (lower heart rate display).
- Watch monitor and mentally try to voluntarily increase sympathetic tone (increase heart rate display).
- Watch two PowerPoint presentations and try to remain relaxed.

KEY FEATURES

- Great introduction to biofeedback techniques.
- Shows the student how they can influence and control the autonomic nervous system.
- Excellent display format for immediate visual feedback.

MATERIALS

- Biopac Science Lab intro system (uses three electrodes per subject)
  PowerPoint Viewer 2003 lets you view full-featured presentations created in PowerPoint 97 and later versions, which can greatly enhance the feedback segments of this lesson.
- Presentation 1 — images or sound
- Presentation 2 — modified
  Presentation 1 with startling sound or image inserted
Lesson 10 — Aerobic Exercise Physiology

In the Aerobic Exercise Physiology lesson, students record ECG and heart rate under a variety of conditions. Students see how the electrical activity of the heart and their heart rate change to meet changing metabolic demands. Students exercise to elevate heart rate.

EXPERIMENTAL OBJECTIVES

- Measure changes in heart rate associated with a specified set of dynamic exercises.
- Assess individual physical fitness by measuring elevated heart rate at the immediate end of a specific exercise period.
- Assess individual physical fitness by measuring the time from the end of exercise to the return of resting heart rate.
- Compare performance levels between groups, such as young women vs. young men, or persons with body weight 75–150 lbs. vs. persons with body weight 151–250 lbs.

TASKS PERFORMED BY THE STUDENT

- Record ECG and heart rate.
- Calculate personal maximum heart rate.
- Sit and relax.
- Exercise (e.g. running in place/jumping jacks) to elevate heart rate.
- Recover from exercise (sit and relax).

KEY FEATURES

- Great introduction to physiological changes associated with exercise.
- The equipment does not interfere with the exercise.
- No expensive exercise equipment required to run the lesson.
Lesson 11 — Reaction Time *Fixed & Pseudo-random Intervals*

The Reaction Time lesson demonstrates the effect of learning and physiological processes on reaction times. Students hear two presentation schedules of clicks through a set of headphones. With electrodes in place to record the activity of the extensor digitorum (the primary muscle used to lift a finger), the Subject lifts finger as quickly as possible after hearing a click. Students then perform a statistical analysis of the results, including: group mean, variance, and standard deviation.

**EXPERIMENTAL OBJECTIVES**
- Measure and compare reaction times of an individual subject using two stimulus presentation schedules: fixed intervals and pseudo-random intervals.
- Introduce elements of statistics into data analysis.
- Use statistics to determine the effects of learning on reaction times.

**TASKS PERFORMED BY THE STUDENT**
- React to a schedule of fixed interval clicks (two trials).
- React to a schedule of pseudo-random clicks (two trials).

**KEY FEATURES**
- The software automatically calculates the reaction time.
- Guides students through the statistical analysis of a data set.
- The lesson will also work with different stimuli.
Lesson 12 — Respiration 1 Apnea

In Respiration 1, students observe physiologic modifications of the respiratory cycle associated with voluntarily increasing and decreasing blood carbon dioxide content by holding breath and hyperventilating. Students will qualitatively determine changes in respiratory minute volume by recording and analyzing EMGs from respiratory muscles of the thorax.

**EXPERIMENTAL OBJECTIVES**

- To observe and record EMGs from thoracic respiratory skeletal muscle during eupnea, or normal unlabored breathing at rest.
- To record changes in the EMG associated with modifications in the rate and depth of the respiratory cycle that occur before, during, and after periods of apnea vera and voluntary apnea and to compare those changes to eupnea.

**TASKS PERFORMED BY THE STUDENT**

- Record EMG and respiration.
- Breathe normally with mouth open.
- Hyperventilate.
- Recover from hyperventilation.
- Hold breath.
- Hyperventilate and then hold breath.

**KEY FEATURES**

- Great introduction to the respiratory effects of increased or decreased blood carbon dioxide content.
- No expensive respiratory equipment required to run the lesson.
- The lesson setup can record and allow students to study other respiratory fluctuations.
National Science Standards

Detail options: Click the ♦ in the table to review the lesson correlation to the specified content standard. Click the content standard link (left column) to view all correlations for that standard. Click the Lesson # (top row) to view all content standards for that Lesson.

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**Content Standard Description—Levels 9-12**

**A3** Unifying Concepts and Processes: Change, Constancy, and Measurement
Students should develop an understanding of the unifying concepts and processes of change, constancy, and measurement.

**A5** Unifying Concepts and Processes: Form and Function
Students should develop an understanding of the unifying concepts and processes of form and function.

**B1** Science as Inquiry: Abilities Necessary to do Scientific Inquiry
Students should develop an understanding of science as inquiry and develop abilities necessary to do scientific inquiry.

**B2** Science as Inquiry: Understandings About Scientific Inquiry
Students should develop understandings about scientific inquiry.

**D5** Life Science: Matter, Energy, and Organization in Living Systems
Students should develop an understanding of matter, energy, and organization in living systems.

**G1** Science in Personal and Social Perspectives: Personal and Community Health
Students should be given a means to understand and act on personal and social issues, to help students develop decision-making skills, and to give students a foundation on which to base decisions they will face as citizens.

**Lesson Descriptions**

- **S01** EMG: Electromyography 1
- **S02** EMG: Electromyography 2
- **S03** EMG: Electrocardiography 1
- **S04** EMG: Electrocardiography 2
- **S05** EEG: Electroencephalography 1
- **S06** EEG: Electroencephalography 2
- **S08** EOG: Electrooculography
- **S09** Biofeedback
- **S10** Aerobic Exercise Physiology
- **S11** Reaction Time
- **S12** Respiration: Apnea
A3 Unifying Concepts and Processes: Change, Constancy, and Measurement

Students should develop an understanding of the unifying concepts and processes of change, constancy, and measurement.

S01—A3 Students investigate properties of skeletal muscle by recording EMG data associated with muscle contraction. They measure and correlate grip strength with recorded changes in the level of EMG activity. By measuring and comparing grip strengths of the dominant and non-dominant hands, they associate changes in skeletal muscle, such as increased strength, with increased use. They listen to audio output generated by the electrical activity associated with muscle contraction and correlate sound intensity with motor unit recruitment.

S02—A3 Students investigate the ability of skeletal muscle to perform mechanical work by recording EMG data associated with muscle contraction. They record and measure EMG responses to increased weights lifted by dominant and non-dominant arms. They associate chronic changes in skeletal muscle, such as increased size and strength, with increased use. They listen to audio output generated by the electrical activity associated with muscle contraction and correlate sound intensity with motor unit recruitment.

S03—A3 Students investigate the human cardiac cycle and associated electrical changes of the heart by recording the electrical signal of the heartbeat. The record of the electrical signal, called an electrocardiogram (ECG), is complex. It is divided into several distinct, sequential events, the duration and intensity of which are constant or may change under varying conditions of normal health such as body position and breathing. Students observe rate, rhythm, and other changes in heart activity by making ECG measurements and analyzing their results.

S04—A3 Students investigate the human cardiac cycle and associated electrical changes of the heart by recording the electrical signal of the heartbeat detected by two recording electrodes placed on the skin. The position of the electrodes is called a lead. The bipolar limb leads are Lead I (right arm- left arm+), Lead II (right arm - left leg +), and Lead III (left arm- left leg+). The ground electrode is placed on the right leg. The record of the electrical signal, called an electrocardiogram (ECG), is a record of voltage changes (millivolts) vs. time (sec). It is divided into several distinct, sequential events, the duration and intensity of which are constant or may change under varying conditions of normal health such as body position and breathing. Students record Leads I and III while performing a number of tasks designed to change the rhythm of the heart. They then compare the Lead I and Lead II records, analyze the data, and estimate the mean QRS axis and the mean ventricular potential.

S05—A3 Students investigate electrical activity of the human brain by recording voltage changes detected by recording electrodes placed on the scalp. The time record of the voltage changes is called an electroencephalogram, or EEG. Students learn the EEG is a complex pattern of waveforms that vary in frequency and amplitude, and that the EEG varies with the mental state of the subject. The EEG changes as the brain grows with age, and it is variable among persons of the same age. Fundamentally, however, the EEG consists of four basic rhythms designated alpha, beta, delta, and theta. Students determine the prominent EEG rhythm under different mental conditions by examining waveform frequency and amplitude.

S06—A3 Students investigate electrical activity of the human brain by recording, measuring, and comparing voltage/frequency changes detected by scalp recording electrodes while performing a number of tasks. Students record and analyze changes in occipital lobe alpha rhythm observed during different experimental conditions.
The time record of the voltage changes is called an electro-encephalogram, or EEG, a complex pattern of waveforms that vary in frequency and amplitude. The EEG varies from lobe to lobe and is influenced by the mental state of the subject.

Fundamentally, the EEG consists of four basic rhythms designated alpha, beta, delta, and theta. The alpha rhythm is the prominent EEG pattern of a relaxed, inattentive state in an adult with the eyes closed. Alpha rhythm is characterized by a frequency of 8-13 Hz and amplitudes of 20-200µV. Alpha waves of the greatest amplitude are recorded from the occipital lobe region of the scalp.

**S08—A3** Students investigate eye movements using temporal skin electrodes to detect and record electrical activity associated with cortical control of extra ocular muscles.

Students record different tasks, recording and measuring the duration of saccades and fixation, and the spatial position of eye movements.

Electrooculography is the measurement and interpretation of electrooculograms (EOG), which are the electroencephalographic tracings obtained while the subject, without moving the head, moves their eyes from one fixation point to another within the visual field.

**S09—A3** Students explore the concept of biofeedback training as a method of influencing output of the autonomic nervous system.

The autonomic nervous system (ANS) regulates visceral activities such as blood pressure and flow, gastrointestinal functions, breathing rate and depth, and so forth. Autonomic control occurs without the need for conscious input from the cerebral cortex. We do not need to think about adjusting blood pressure, for example, when we begin to exercise. The adjustment occurs automatically by way of the ANS.

A widely held belief is that ANS control of visceral function cannot be altered by conscious input, that autonomic control is essentially, and necessarily, automatic. In this lesson, students explore the concept of biofeedback training as a method of influencing output of the autonomic nervous system by measuring changes in heart rate induced through application of a biofeedback technique.

**S10—A3** Students record their electrocardiogram and heart rate at rest and during and after a specific set of dynamic exercises. Students measure changes in the electrocardiogram and heart rate and see how they change to meet the metabolic demands of physical exercise.

**S11—A3** Students measure reaction times and see how easily and rapidly a person learns, as demonstrated by his/her ability to anticipate when to press a button in response to an audible signal. As a person learns what to expect, reaction time typically decreases.

Reaction time is the interval between when a stimulus is presented and when the response to the stimulus occurs. Learning, the acquisition of knowledge or skills due to experience and/or instruction, can alter reaction time in some stimulus-response situations.

**S12—A3** Two principle functions of the human respiratory system are to supply oxygen to the blood and remove carbon dioxide from the blood. When the body is at rest, the rate and depth of breathing is stable and matches the body’s needs for oxygen absorption and carbon dioxide removal.

Students learn that blood levels of carbon dioxide influence the rate and depth of breathing. When blood carbon dioxide increases above resting levels, as during physical exercise or after breath-holding, the rate and depth of breathing increases. When blood carbon dioxide decreases below resting levels as a result of voluntary hyperventilation or over-breathing, respiratory rate and depth decrease. Students record and measure changes in respiratory rate and depth associated with induced changes in blood carbon dioxide.

**A5 Unifying Concepts and Processes: Form and Function**

Students should develop an understanding of the unifying concepts and processes of form and function.

**S01—A5** Students associate skeletal muscle work with skeletal muscle contraction. Because of the way skeletal muscles are attached to the skeleton, contracting skeletal muscles work by pulling on parts of the
skeleton, not by pushing. Students learn about the motor unit organization of skeletal muscle and correlate the strength of a skeletal muscle’s contraction and its ability to perform mechanical work with the structure and number of motor units.

**S02—A5** Students learn about the motor unit organization of skeletal muscle and correlate the strength of a skeletal muscle’s contraction and its ability to perform mechanical work with the structure and number of active motor units. Students observe that the increased number of motor units activated when an increased amount of weight is lifted is directly proportional to the increased amount of mechanical work muscles are asked to perform.

**S03—A5** Students learn that the form of the ECG, such as wave amplitudes, depends in part on the position of the heart in the chest, and the positions of the recording electrodes on the surface of the body. Students also learn to associate the structure of the heart and its internal conduction system with the sequential, individual events of the ECG.

**S04—A5** Students learn that the form of the ECG, such as wave amplitudes, depends in part on the position of the heart in the chest, and the positions of the recording electrodes on the surface of the body. Students examine the relationship between the bipolar limb lead recordings known as Einthoven’s law.

The three bipolar limb leads can be arranged to form an electrical equilateral triangle, called Einthoven’s triangle. The heart is in the center of the triangle. Einthoven’s law says if the amplitude values of the wave forms in any two bipolar limb lead recordings are known, the amplitude values of the waveforms in the non-recorded bipolar limb lead can be mathematically determined.

**S05—A5** Students learn that the prominent EEG wave pattern is correlated to the subject’s mental state and can be influenced by the location of the scalp electrodes. Students record the EEG from the occipital lobe, the part of the brain involved with processing visual information. The EEG is recorded from an awake, resting subject with eyes open and eyes closed.

**S06—A5** A primary function of the cortex of the occipital lobe is the processing and storage of information related to the special sense of vision or sight. In this lesson, students examine differences in the level of alpha rhythm activity during mental arithmetic and hyperventilation compared to the control condition of eyes closed and relaxed.

**S08—A5** Students learn that binocular vision requires precisely coordinated involuntary eye movements that are initiated and controlled in the motor cortex of the frontal lobes. Coordinated control of the extraocular muscles allows the eyes to maintain clear focus on objects that are either fixed or moving in the visual field by ensuring that light reflected from the object (pendulum, written word, etc.) falls on corresponding parts of the retinas.

**S10—A5** Students learn that a regular program of physical exercise increases skeletal muscle size and promotes the growth of blood vessels that supply oxygen and nutrients to the muscle and remove metabolic wastes. The adaptations and physiological changes that develop during chronic exercise generally result in an increased ability of the muscle to perform work at greater levels of intensity, and an increased capacity to work at any given level for a longer period of time before fatiguing. A physically fit person tends to have a lower heart rate at rest and immediately after moderate exercise than does an unfit person.

**S11—A5** Students learn that the ability to either involuntarily or voluntarily respond to a stimulus is dependent on a reflex or stimulus-response pathway.

Physiologically, a reflex, or a stimulus-response begins with the application of a stimulus to a sensory receptor, such as an auditory hair cell, and ends with a response by an effector, such as a skeletal muscle.

Anatomical elements of the pathway include a sensory receptor, a sensory or afferent neuron, an integrating center in the brain or spinal cord, a motor or efferent neuron, and an effector.

**S12—A5** The human lungs occupy air-tight compartments within the thorax or chest. Students learn that contraction of chest muscles increases volume of the thorax and lungs which results in air pressure
inside the lungs falling below atmospheric pressure and air moving into the lungs. These events characterize inspiration.

Expiration, or the exhaling of air from the lungs occurs at rest when inspiratory muscles relax, decreasing the volume of the lungs and the thorax, thereby increasing pressure within the lungs above atmospheric pressure, forcing air out of the lungs.

**B1 Science as Inquiry: Abilities Necessary to do Scientific Inquiry**

Students should develop an understanding of science as inquiry and develop abilities necessary to do scientific inquiry:

**S01—B1** Students learn that some functions of skeletal muscle can be investigated using electromyography as a tool. They analyze individual experimental data and are encouraged to share data and perform cross-group analyses. They are encouraged to share results and to suggest reasons for observed differences. Through the applications of electromyography and their observations about muscle function, students are encouraged to ask additional questions about skeletal muscle functions and to suggest methods of obtaining answers.

**S02—B1** Students learn that some aspects of the ability of skeletal muscles to perform mechanical work can be investigated using electromyography as a tool. They analyze individual experimental data regarding performance of mechanical work and time to fatigue, compare differences between male and female students, and are encouraged to suggest reasons for observed differences. Through the applications of electromyography and their observations about muscle function, students are encouraged to ask additional questions about skeletal muscle functions and to suggest methods of obtaining answers.

**S03—B1** Students correlate electrical events of the cardiac cycle with mechanical events of the cardiac cycle and learn that normal and abnormal heart functions may be investigated by using electrocardiography as a tool. They learn about normal elements of the ECG recorded using Lead II, and then explore ECG changes that may result from breathing and from changing body position with respect to gravity. Students are encouraged to compare data with other subjects to see if body size, age, or gender influence ECG values. They are also encouraged to think about and explore, using the ECG as a tool, other factors that may influence heart activity and the ECG.

**S04—B1** Students learn that normal and abnormal heart functions may be investigated by using electrocardiography as a tool. They are introduced to principles of planar or two-dimensional vectorcardiography, calculate and graph the mean ventricular potential and mean QRS axis, and explore ECG changes that may result from breathing and from changing body position with respect to gravity.

Students are encouraged to compare data with other subjects to see if body size, age, or gender influence ECG values. They are also encouraged to think about and explore, using the ECG as a tool, other factors that may influence heart activity and the ECG.

**S05—B1** Students correlate electrical activity of the brain with the performance of various tasks, and determine the prominent EEG waveforms associated with specific tasks. Students learn that the prominent EEG rhythm of a resting, alert subject with eyes open is the beta rhythm, and that the alpha rhythm is associated with the relaxed, inattentive, eyes closed state. Students are encouraged to compare differences between male and female students, and to suggest methods of exploring other factors that might account for the variability of the EEG.

**S06—B1** Students record an EEG from the occipital lobe region of an awake, resting subject under the following conditions: relaxed with eyes closed, performing mental arithmetic with eyes closed, hyperventilating (breathing quickly and deeply), and relaxed with eyes open.

Students are encouraged to offer explanations for the observed EEG changes, and are encouraged to compare differences between male and female students. They are encouraged to suggest methods of exploring other factors that might account for the variability of the EEG.

**S08—B1** Students correlate electrical activity of the brain and extra ocular muscles with the performance of various visual tasks such as tracking a swinging pendulum, simulating tracking eye movement with...
eyes closed, reading silently, reading aloud, and reading difficult material. They measure and compare the duration of saccades and fixation. Using their laboratory experience as a foundation, they are encouraged to ask other questions about visual control systems and to explore microsaccadic eye movement.

**S9—B1** Students are introduced to principles of sympathetic and parasympathetic autonomic nervous control and the concept of biofeedback training and how it can be used to study autonomic function.

Students record their ECG as an on-screen, thermometer-style heart rate display rises and falls with changes in heart rate, allowing the student to become conscious of his/her heart rate. The subject then mentally tries, without physical movement, to increase or to decrease the heart rate reading while watching the monitor.

**S10—B1** Students learn that physical fitness can be assessed by measuring changes in heart rate associated with a specific set of dynamic exercises, such as performing jumping jacks, running in place, or stepping up and down in place. Students record the resting ECG and heart rate, the exercise ECG and increase in heart rate at the immediate end of an exercise period, and the time it takes from the end of the exercise period to the return of resting ECG and heart rate. They compare measured values with normalized data based on gender, age, and body weight. They compare performance levels between groups, such as young women vs. young men, or persons with body weight 75 – 150 lbs. vs. persons with body weight 151 – 250 lbs.

**S11—B1** Students measure and compare reaction times of an individual subject using two stimulus presentation schedules: fixed intervals, and pseudo-random intervals.

Students are introduced to elements of statistics and their application in data analysis, and use statistics to determine the effects of learning on reaction times. They discover that when pseudo-random presentation trials are repeated, it takes longer for reaction times to decrease and the decrease is less than as occurs with fixed-interval presentation.

**S12—B1** Students observe and record EMGs (electromyograms) from thoracic respiratory skeletal muscle during eupnea, or normal unlabored breathing at rest. Changes in the EMG are associated with modifications in the rate and depth of the respiratory cycle that occur before, during, and after periods of apnea vera and voluntary apnea (cessation of breathing). Students compare changes in the EMG associated with apnea to the EMG recorded during eupnea.

**B2 Science as Inquiry: Understandings About Scientific Inquiry**

Students should develop understandings about scientific inquiry.

**S01—B2** Based on their laboratory experience with electromyography and its applications in the study of muscle function, students appreciate the limitations in using one method. Other questions about muscle function cannot be answered using electromyographic techniques, and therefore must be answered by applying different investigative tools and methods.

**S02—B2** Based on their laboratory experience with electromyography and its applications in the study of muscle function, students appreciate the limitations in using one method. Other questions about muscle function cannot be answered using electromyographic techniques, and therefore must be answered by applying different investigative tools and methods.

**S03—B2** Based on their laboratory experience with Lead II electrocardiography, students learn that although electrocardiography is a useful tool in exploring and understanding basic functions of the heart, its usefulness is limited. For example, the human ECG is not very useful for predicting a heart attack but can be very useful for determining the location and extent of damage after a heart attack has occurred.

**S04—B2** Based on their laboratory experience with bipolar limb lead electrocardiography and vectorcardiography, students learn that although electrocardiography and vectorcardiography are useful tools in exploring and understanding basic functions of the heart, their usefulness is limited. For example, neither electrocardiography nor vectorcardiography are very useful for predicting a heart attack but they can be very useful for determining the location and extent of damage after a heart attack has occurred.
Electroencephalography used as tool to investigate functions of the human brain, like may other tools of neural science, has limited usefulness, and its usefulness depends on proper application. Based on their introductory laboratory experience with electroencephalography, students learn that answers to questions about brain function often require the application of more than one investigative tool.

Students learn that the recording of electrical activity detected by skin electrodes placed lateral to the eyes can be used to study and understand visual phenomena associated with concerted eyeball movement. However, information gained through the application of electrooculography is limited, and therefore other methods of investigation must be employed to answer questions about the visual system.

Students learn about the basic functions and tone of the sympathetic and the parasympathetic divisions of the autonomic nervous system, and, the long-held tenant that autonomic functions are independent of the will. They experiment with biofeedback, a relatively recent clinical technique, to test the tenant and find that within limits it is possible to consciously alter autonomic tone. Based on their laboratory experience with biofeedback, students learn that newer technologies can be adapted to re-examine the validity of older hypotheses long held to be true.

Students are encouraged to think about and explore other methods of biofeedback that could prove useful in voluntarily altering autonomic tone, and to think of reasons why this might be beneficial.

Students are asked to think about other physiological changes related to exercise that could be measured and used as an index of physical fitness. On the basis of their laboratory experience using heart rate changes to evaluate physical fitness, and laboratory discussion, students see that changes, such as systemic blood pressure, or respiratory rate and depth, offer other avenues for assessing physical fitness. Students begin to understand that each measure is of limited value, and no single measure of physical fitness is best.

Students take a relatively simple look at reaction time and how changing one variable, stimulus presentation interval, can result in differences in reaction time. Students realize that other factors could influence reaction time and are encouraged to think about and explore them using their laboratory experience. For example, a person’s reaction time could be measured and compared in two different conditions, such as reading a book vs. watching TV.

Students use respiratory electromyography to study changes in respiratory rate and depth associated with changes in blood carbon dioxide. They learn that electromyographic methods allow only for qualitative assessment of the changes. Quantitative measurements of changes in respiratory cycle depth and more exact measurements of changes in respiratory rate require the application of more sophisticated technology and analytical techniques. Thus, the results obtained from scientific inquiry are limited by the nature of the applied methods.

**D5 Life Science: Matter, Energy, and Organization in Living Systems**

Students should develop an understanding of matter, energy, and organization in living systems.

Students learn about the basic structural and functional relationships between the nervous system and the muscular system. They develop an understanding of how the organization of the two systems allows for precise and efficient control of skeletal muscle contraction.

Based on their laboratory experience with electromyography and its applications in the study of muscle function, students appreciate the limitations in using one method. Other questions about muscle function cannot be answered using electromyographic techniques, and therefore must be answered by applying different investigative tools and methods.

Students learn that the human heart is a four-chambered structure. Two atrial chambers receive blood from venous systems and pump it to the ventricles. Two ventricular chambers receive blood from the
atria and pump blood into arterial systems. In order for adequate circulation of blood to be sustained, the contraction / relaxation periods of the atria and the ventricles must be very carefully coordinated so that their actions do not oppose one another. The cardiac pacemaker system acts as an electrical coordinator during each heartbeat. The electrical activities associated with this coordination are recorded in the ECG.

S05—D5 The cerebrum is divided into hemispheres and each hemisphere is divided into frontal, parietal, temporal, and occipital lobes. Each lobe has functions that are unique but each lobe also shares functions with other lobes.

For example, as a child, we may see (occipital lobe) a flame and touch (frontal lobe) it to see what it is like, experiencing heat and pain (parietal lobe) and remembering (temporal lobe) not to repeat the experience. These functions and others such as reasoning and abstract thought occur in the outermost part of the cerebrum called the cortex. The electrical activities of the cortex are recorded as an EEG.

S06—D5 The cerebrum is divided into hemispheres and each hemisphere is divided into frontal, parietal, temporal, and occipital lobes. Each lobe has functions that are unique but each lobe also shares functions with other lobes.

For example, as a child, we may see (occipital lobe) a flame and touch (frontal lobe) it to see what it is like, experiencing heat and pain (parietal lobe) and remembering (temporal lobe) not to repeat the experience. These functions and others such as reasoning and abstract thought occur in the outermost part of the cerebrum called the cortex. The electrical activities of the cortex are recorded as an EEG.

S08—D5 The visual system of the human is complex. Normal stereoscopic vision requires receptors in the retinas to convert light energy into nerve impulses which are transmitted to several parts of the brain for processing, giving us the sense of sight. Although we see with two eyes, our brain forms a single image of a three-dimensional object with a perception of depth because concerted control of the extra ocular muscles allows each eye to be positioned so that light reflected from the object is focused on corresponding parts of the retinas. As we visually track the movement of an object in our visual field, the motor control system maintains this retinal correspondence while simultaneously maintaining gaze by moving the eyeballs in their orbits.

S09—D5 The human nervous system and the endocrine system control functions of all the other body systems. Students learn that nervous control involves voluntary and involuntary mechanisms, both of which serve to maintain homeostasis. Involuntary control is the domain of the sympathetic and parasympathetic divisions of the ANS.

Generally speaking, the divisions of the ANS have opposing actions controlling the function of a target organ. For example, an increase in sympathetic activity increases the heart rate; however, an increase in parasympathetic activity decreases heart rate. The two divisions work simultaneously and cooperatively to adjust visceral functions to meet body needs according to changes in the internal and external environment.

S11—D5 Students learn that a reflex is an involuntary or automatic, programmed motor response to a sensory stimulus. Literally, the word reflex is derived from a term meaning to reflect, or return back, with reference to the direction of travel of first the sensory impulses and then the motor impulses along the reflex pathway. Touching a hot object and jerking the hand away, or stepping on a tack and lifting the injured bare foot are examples of simple human reflexes. Reflexes in animals represent the earliest organization of neurons into a functional unit. Even in adult animals that lack a brain, such as a jellyfish, neurons have become specialized and organized to provide for simple, often life-preserving, reflex responses. In the human, reflex activities appear about five months before birth. Reflexes allow the body to react automatically and involuntarily to a variety of internal and external stimuli so as to maintain homeostasis.

A stimulus-response is functionally similar to a reflex except that it is voluntary rather than involuntary, and as such, it can be learned and is subject to behavioral modification. An example is lifting a finger in response to an audible click.

S12—D5 Students learn that all living cells of the body require oxygen to derive energy from food. Stored chemical energy is used by cells to perform work. Cells produce carbon dioxide as a waste product of
metabolism. The respiratory system works in conjunction with the circulatory system to deliver oxygen to the cells and remove carbon dioxide.

G1 Science in Personal and Social Perspectives: Personal and Community Health

Students should be given a means to understand and act on personal and social issues, to help students develop decision-making skills, and to give students a foundation on which to base decisions they will face as citizens.

S02—G1 Given the current and general interest in the control of body weight through exercise and diet control for the purposes of preventing disease and maintaining a healthy lifestyle, it is important for students to learn about basic, normal functions of skeletal muscle. These functions involve the abilities and limitations of skeletal muscle in the performance of mechanical work, and the phenomenon of skeletal muscle fatigue.

S03—G1 Electrocardiography is routinely used in medical practice. The well-informed adult should be aware of both the usefulness of this diagnostic tool and its limitations in providing healthcare professionals with the information they need to minister proper care. This lesson helps students build a foundation on which to base the personal health decisions they will face as adults.

S04—G1 Electrocardiography and vectorcardiography are routinely used in medical practice and offer the cardiologist additional tools with which to assess normal and abnormal heart function. The well-informed adult should be aware of both the usefulness of these diagnostic tools and their limitations in providing healthcare professionals with the information they need to minister proper care. This lesson helps students build a foundation on which to base the personal health decisions they will face as adults.

S05—G1 Electroencephalography is often used in diagnostic neurology and investigative neural science. A good example is its application in the diagnosis, treatment, and study of various forms of epilepsy. The well-informed adult should be aware of both the usefulness of this diagnostic tool and its limitations in providing healthcare professionals with the information they need to minister proper care. This lesson helps students build a foundation on which to base the personal health decisions they will face as adults.

S06—G1 Electroencephalography is often used in diagnostic neurology and investigative neural science. A good example is its application in the diagnosis, treatment, and study of various forms of epilepsy. The well-informed adult should be aware of both the usefulness of this diagnostic tool and its limitations in providing healthcare professionals with the information they need to minister proper care. This lesson helps students build a foundation on which to base the personal health decisions they will face as adults.

S08—G1 Electrooculography is commonly used to assess visual defects involving neuromuscular control of the eyes, such as in diagnosis and treatment success of sixth nerve palsy (paralysis of the lateral rectus). Similar eye movement/cranial nerve tests using other cardinal gazes may be employed in the diagnosis and assessment of eye disorders. Recent applications of electrooculography involve the design of robotics, such as motorized wheelchairs and other devices that can be guided or otherwise controlled by movement of the subject’s eyes.

S09—G1 Mental or psychological stress increases sympathetic activity and decreases parasympathetic activity, resulting in an increase in heart rate, an increase in blood pressure, reduced gastrointestinal functions, and so forth. Over the short term, these changes may be beneficial, but when they are prolonged or become chronic, they become detrimental and can cause disease. Using heart rate biofeedback techniques, an affected person can be taught to relax and to increase parasympathetic tone and thus reduce sympathetic activity, evidenced by a decrease in heart rate. Initially, a machine monitors heart rate and provides the feedback signals that help the subject develop voluntary control. Eventually, the subject is able to recognize and control reactions to stress on his own by recalling and eliciting the same relaxed state of mind used in the biofeedback laboratory when he is at home or at work. Relaxation training using biofeedback has been successfully applied to the management of asthma,
cerebral palsy, hypertension, migraine headache, irritable bowel syndrome, and numerous other maladies.

**S10—G1** Physiological adaptations to chronic exercise, initiated by even the most modest physical activity, play a major role in the prevention of obesity, hypertension and other cardiovascular diseases, respiratory disease, adult-onset (type II) diabetes, and other maladies associated with sedentary lifestyles. This lesson helps make students aware of the value and the need as adults to maintain a healthy lifestyle that includes regular exercise.

**S11—G1** Usually, longer reaction times are a sign that the person is paying less attention to the stimulus and/or is processing other information. For example, if you took more time to respond to audible clicks while also reading a book than when you were also watching TV then you could infer that you were probably paying more attention to the book than to the TV since your brain took longer to respond.

Assessments from simple reaction time tests allow researchers a glimpse into the cognitive and neurological functioning of people as they perform tasks. Of current topical interest is the question of whether concurrent use of cell phones while driving an automobile impairs judgment and slows the driver's reaction time.

**S12—G1** The normal person exhales carbon dioxide as fast as the body produces it so that blood carbon dioxide remains within normal limits. In diseases or conditions in which a person subconsciously hyper-ventilates, such as in chronic anxiety states, blood carbon dioxide may fall too low, removing the main stimulus to breathe, resulting in temporary apnea, dizziness, and fainting. Anxiety states are common in contemporary cultures.

On the other hand, if blood carbon dioxide is permitted to rise above normal, as would occur if a child held his breath to spite his parents, the elevated carbon dioxide would soon become a too powerful stimulus for the brain to ignore and breathing would automatically resume.
**S01 Electromyography 1**

**A3 Unifying Concepts and Processes: Change, Constancy, and Measurement**

Students should develop an understanding of the unifying concepts and processes of change, constancy, and measurement.

**S01**—Students investigate properties of skeletal muscle by recording EMG data associated with muscle contraction. They measure and correlate grip strength with recorded changes in the level of EMG activity. By measuring and comparing grip strengths of the dominant and non-dominant hands, they associate changes in skeletal muscle, such as increased strength, with increased use. They listen to audio output generated by the electrical activity associated with muscle contraction and correlate sound intensity with motor unit recruitment.

**A5 Unifying Concepts and Processes: Form and Function**

Students should develop an understanding of the unifying concepts and processes of form and function.

**S01**—Students associate skeletal muscle work with skeletal muscle contraction. Because of the way skeletal muscles are attached to the skeleton, contracting skeletal muscles work by pulling on parts of the skeleton, not by pushing. Students learn about the motor unit organization of skeletal muscle and correlate the strength of a skeletal muscle’s contraction and its ability to perform mechanical work with the structure and number of motor units.

**B1 Science as Inquiry: Abilities Necessary to do Scientific Inquiry**

Students should develop an understanding of science as inquiry and develop abilities necessary to do scientific inquiry.

**S01**—Students learn that some functions of skeletal muscle can be investigated using electromyography as a tool. They analyze individual experimental data and are encouraged to share data and perform cross-group analyses. They are encouraged to share results and to suggest reasons for observed differences. Through the applications of electromyography and their observations about muscle function, students are encouraged to ask additional questions about skeletal muscle functions and to suggest methods of obtaining answers.

**B2 Science as Inquiry: Understandings About Scientific Inquiry**

Students should develop understandings about scientific inquiry.

**S01**—Based on their laboratory experience with electromyography and its applications in the study of muscle function, students appreciate the limitations in using one method. Other questions about muscle function cannot be answered using electromyographic techniques, and therefore must be answered by applying different investigative tools and methods.

**D5 Life Science: Matter, Energy, and Organization in Living Systems**

Students should develop an understanding of matter, energy, and organization in living systems.

**S01**—Students learn about the basic structural and functional relationships between the nervous system and the muscular system. They develop an understanding of how the organization of the two systems allows for precise and efficient control of skeletal muscle contraction.

**S02 Electromyography 2**

**A3 Unifying Concepts and Processes: Change, Constancy, and Measurement**

Students should develop an understanding of the unifying concepts and processes of change, constancy, and measurement.

**S02**—Students investigate the ability of skeletal muscle to perform mechanical work by recording EMG data associated with muscle contraction. They record and measure EMG responses to increased weights lifted by dominant and non-dominant arms. They associate chronic changes in skeletal muscle, such as increased size and strength, with increased use. They listen to audio output generated by the electrical activity associated with muscle contraction and correlate sound intensity with motor unit recruitment.
A5 Unifying Concepts and Processes: Form and Function

Students should develop an understanding of the unifying concepts and processes of form and function.

S02—Students learn about the motor unit organization of skeletal muscle and correlate the strength of a skeletal muscle’s contraction and its ability to perform mechanical work with the structure and number of active motor units. Students observe that the increased number of motor units activated when an increased amount of weight is lifted is directly proportional to the increased amount of mechanical work muscles are asked to perform.

B1 Science as Inquiry: Abilities Necessary to do Scientific Inquiry

Students should develop an understanding of science as inquiry and develop abilities necessary to do scientific inquiry.

S02—Students learn that some aspects of the ability of skeletal muscles to perform mechanical work can be investigated using electromyography as a tool. They analyze individual experimental data regarding performance of mechanical work and time to fatigue, compare differences between male and female students, and are encouraged to suggest reasons for observed differences. Through the applications of electromyography and their observations about muscle function, students are encouraged to ask additional questions about skeletal muscle functions and to suggest methods of obtaining answers.

B2 Science as Inquiry: Understandings About Scientific Inquiry

Students should develop understandings about scientific inquiry.

S02—Based on their laboratory experience with electromyography and its applications in the study of muscle function, students appreciate the limitations in using one method. Other questions about muscle function cannot be answered using electromyographic techniques, and therefore must be answered by applying different investigative tools and methods.

D5 Life Science: Matter, Energy, and Organization in Living Systems

Students should develop an understanding of matter, energy, and organization in living systems.

S02—Based on their laboratory experience with electromyography and its applications in the study of muscle function, students appreciate the limitations in using one method. Other questions about muscle function cannot be answered using electromyographic techniques, and therefore must be answered by applying different investigative tools and methods.

G1 Science in Personal and Social Perspectives: Personal and Community Health

Students should be given a means to understand and act on personal and social issues, to help students develop decision-making skills, and to give students a foundation on which to base decisions they will face as citizens.

S02—Given the current and general interest in the control of body weight through exercise and diet control for the purposes of preventing disease and maintaining a healthy lifestyle, it is important for students to learn about basic, normal functions of skeletal muscle. These functions involve the abilities and limitations of skeletal muscle in the performance of mechanical work, and the phenomenon of skeletal muscle fatigue.
A3 **Unifying Concepts and Processes: Change, Constancy, and Measurement**

Students should develop an understanding of the unifying concepts and processes of change, constancy, and measurement.

_S03—Students investigate the human cardiac cycle and associated electrical changes of the heart by recording the electrical signal of the heartbeat._

The record of the electrical signal, called an electrocardiogram (ECG), is complex. It is divided into several distinct, sequential events, the duration and intensity of which are constant or may change under varying conditions of normal health such as body position and breathing. Students observe rate, rhythm, and other changes in heart activity by making ECG measurements and analyzing their results.

A5 **Unifying Concepts and Processes: Form and Function**

Students should develop an understanding of the unifying concepts and processes of form and function.

_S03—Students learn that the form of the ECG, such as wave amplitudes, depends in part on the position of the heart in the chest, and the positions of the recording electrodes on the surface of the body. Students also learn to associate the structure of the heart and its internal conduction system with the sequential, individual events of the ECG._

B1 **Science as Inquiry: Abilities Necessary to do Scientific Inquiry**

Students should develop an understanding of science as inquiry and develop abilities necessary to do scientific inquiry.

_S03—Students correlate electrical events of the cardiac cycle with mechanical events of the cardiac cycle and learn that normal and abnormal heart functions may be investigated by using electrocardiography as a tool. They learn about normal elements of the ECG recorded using Lead II, and then explore ECG changes that may result from breathing and from changing body position with respect to gravity. Students are encouraged to compare data with other subjects to see if body size, age, or gender influence ECG values. They are also encouraged to think about and explore, using the ECG as a tool, other factors that may influence heart activity and the ECG._

B2 **Science as Inquiry: Understandings About Scientific Inquiry**

Students should develop understandings about scientific inquiry.

_S03—Based on their laboratory experience with Lead II electrocardiography, students learn that although electrocardiography is a useful tool in exploring and understanding basic functions of the heart, its usefulness is limited. For example, the human ECG is not very useful for predicting a heart attack but can be very useful for determining the location and extent of damage after a heart attack has occurred._

D5 **Life Science: Matter, Energy, and Organization in Living Systems**

Students should develop an understanding of matter, energy, and organization in living systems.

_S03—Students learn that the human heart is a four-chambered structure. Two atrial chambers receive blood from venous systems and pump it to the ventricles. Two ventricular chambers receive blood from the atria and pump blood into arterial systems. In order for adequate circulation of blood to be sustained, the contraction / relaxation periods of the atria and the ventricles must be very carefully coordinated so that their actions do not oppose one another. The cardiac pacemaker system acts as an electrical coordinator during each heartbeat. The electrical activities associated with this coordination are recorded in the ECG._
G1 Science in Personal and Social Perspectives: Personal and Community Health

Students should be given a means to understand and act on personal and social issues, to help students develop decision-making skills, and to give students a foundation on which to base decisions they will face as citizens.

S03—Electrocardiography is routinely used in medical practice. The well-informed adult should be aware of both the usefulness of this diagnostic tool and its limitations in providing healthcare professionals with the information they need to minister proper care. This lesson helps students build a foundation on which to base the personal health decisions they will face as adults.

S04 Electrocardiography 2

A3 Unifying Concepts and Processes: Change, Constancy, and Measurement

Students should develop an understanding of the unifying concepts and processes of change, constancy, and measurement.

S04—Students investigate the human cardiac cycle and associated electrical changes of the heart by recording the electrical signal of the heartbeat detected by two recording electrodes placed on the skin.

The position of the electrodes is called a lead. The bipolar limb leads are Lead I (right arm - left arm +), Lead II (right arm - left leg +), and Lead III (left arm - left leg +). The ground electrode is placed on the right leg.

The record of the electrical signal, called an electrocardiogram (ECG), is a record of voltage changes (millivolts) vs. time (sec). It is divided into several distinct, sequential events, the duration and intensity of which are constant or may change under varying conditions of normal health such as body position and breathing.

Students record Leads I and III while performing a number of tasks designed to change the rhythm of the heart. They then compare the Lead I and Lead II records, analyze the data, and estimate the mean QRS axis and the mean ventricular potential.

A5 Unifying Concepts and Processes: Form and Function

Students should develop an understanding of the unifying concepts and processes of form and function.

S04—Students learn that the form of the ECG, such as wave amplitudes, depends in part on the position of the heart in the chest, and the positions of the recording electrodes on the surface of the body. Students examine the relationship between the bipolar limb lead recordings known as Einthoven’s law.

The three bipolar limb leads can be arranged to form an electrical equilateral triangle, called Einthoven’s triangle. The heart is in the center of the triangle. Einthoven’s law says if the amplitude values of the waveforms in any two bipolar limb lead recordings are known, the amplitude values of the waveforms in the non-recorded bipolar limb lead can be mathematically determined.

B1 Science as Inquiry: Abilities Necessary to do Scientific Inquiry

Students should develop an understanding of science as inquiry and develop abilities necessary to do scientific inquiry.

S04—Students learn that normal and abnormal heart functions may be investigated by using electrocardiography as a tool. They are introduced to principles of planar or two-dimensional vectorcardiography, calculate and graph the mean ventricular potential and mean QRS axis, and explore ECG changes that may result from breathing and from changing body position with respect to gravity.

Students are encouraged to compare data with other subjects to see if body size, age, or gender influence ECG values. They are also encouraged to think about and explore, using the ECG as a tool, other factors that may influence heart activity and the ECG.

B2 Science as Inquiry: Understandings About Scientific Inquiry

Students should develop understandings about scientific inquiry.

S04—Based on their laboratory experience with bipolar limb lead electrocardiography and vectorcardiography, students learn that although electrocardiography and vectorcardiography are useful
tools in exploring and understanding basic functions of the heart, their usefulness is limited. For example, neither electrocardiography nor vectorcardiography are very useful for predicting a heart attack but they can be very useful for determining the location and extent of damage after a heart attack has occurred.

G1 Science in Personal and Social Perspectives: Personal and Community Health
Students should be given a means to understand and act on personal and social issues, to help students develop decision-making skills, and to give students a foundation on which to base decisions they will face as citizens.

S04—Electrocardiography and vectorcardiography are routinely used in medical practice and offer the cardiologist additional tools with which to assess normal and abnormal heart function. The well-informed adult should be aware of both the usefulness of these diagnostic tools and their limitations in providing healthcare professionals with the information they need to minister proper care. This lesson helps students build a foundation on which to base the personal health decisions they will face as adults.

S05 Electroencephalography 1

A3 Unifying Concepts and Processes: Change, Constancy, and Measurement
Students should develop an understanding of the unifying concepts and processes of change, constancy, and measurement.

S05—Students investigate electrical activity of the human brain by recording voltage changes detected by recording electrodes placed on the scalp. The time record of the voltage changes is called an electroencephalogram, or EEG.

Students learn the EEG is a complex pattern of waveforms that vary in frequency and amplitude, and that the EEG varies with the mental state of the subject.

The EEG changes as the brain grows with age, and it is variable among persons of the same age. Fundamentally, however, the EEG consists of four basic rhythms designated alpha, beta, delta, and theta.

Students determine the prominent EEG rhythm under different mental conditions by examining waveform frequency and amplitude.

A5 Unifying Concepts and Processes: Form and Function
Students should develop an understanding of the unifying concepts and processes of form and function.

S05—Students learn that the prominent EEG wave pattern is correlated to the subject’s mental state and can be influenced by the location of the scalp electrodes. Students record the EEG from the occipital lobe, the part of the brain involved with processing visual information. The EEG is recorded from an awake, resting subject with eyes open and eyes closed.

B1 Science as Inquiry: Abilities Necessary to do Scientific Inquiry
Students should develop an understanding of science as inquiry and develop abilities necessary to do scientific inquiry.

S05—Students correlate electrical activity of the brain with the performance of various tasks, and determine the prominent EEG waveforms associated with specific tasks. Students learn that the prominent EEG rhythm of a resting, alert subject with eyes open is the beta rhythm, and that the alpha rhythm is associated with the relaxed, inattentive, eyes closed state. Students are encouraged to compare differences between male and female students, and to suggest methods of exploring other factors that might account for the variability of the EEG.

B2 Science as Inquiry: Understandings About Scientific Inquiry
Students should develop understandings about scientific inquiry.

S05—Electroencephalography used as tool to investigate functions of the human brain, like may other tools of neural science, has limited usefulness, and its usefulness depends on proper application. Based on their introductory laboratory experience with electroencephalography, students learn that answers to questions about brain function often require the application of more than one investigative tool.

D5 Life Science: Matter, Energy, and Organization in Living Systems
Students should develop an understanding of matter, energy, and organization in living systems.
The cerebrum is divided into hemispheres and each hemisphere is divided into frontal, parietal, temporal, and occipital lobes. Each lobe has functions that are unique but each lobe also shares functions with other lobes.

For example, as a child, we may see (occipital lobe) a flame and touch (frontal lobe) it to see what it is like, experiencing heat and pain (parietal lobe) and remembering (temporal lobe) not to repeat the experience. These functions and others such as reasoning and abstract thought occur in the outermost part of the cerebrum called the cortex. The electrical activities of the cortex are recorded as an EEG.

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**G1 Science in Personal and Social Perspectives: Personal and Community Health**

Students should be given a means to understand and act on personal and social issues, to help students develop decision-making skills, and to give students a foundation on which to base decisions they will face as citizens.

**S05—Electroencephalography** is often used in diagnostic neurology and investigative neural science. A good example is its application in the diagnosis, treatment, and study of various forms of epilepsy. The well-informed adult should be aware of both the usefulness of this diagnostic tool and its limitations in providing healthcare professionals with the information they need to minister proper care. This lesson helps students build a foundation on which to base the personal health decisions they will face as adults.

**S06 Electroencephalography 2**

**A3 Unifying Concepts and Processes: Change, Constancy, and Measurement**

Students should develop an understanding of the unifying concepts and processes of change, constancy, and measurement.

**S06—Students investigate electrical activity of the human brain by recording, measuring, and comparing voltage/frequency changes detected by scalp recording electrodes while performing a number of tasks. Students record and analyze changes in occipital lobe alpha rhythm observed during different experimental conditions.**

The time record of the voltage changes is called an electro-encephalogram, or EEG, a complex pattern of waveforms that vary in frequency and amplitude. The EEG varies from lobe to lobe and is influenced by the mental state of the subject.

Fundamentally, the EEG consists of four basic rhythms designated alpha, beta, delta, and theta. The alpha rhythm is the prominent EEG pattern of a relaxed, inattentive state in an adult with the eyes closed. Alpha rhythm is characterized by a frequency of 8-13 Hz and amplitudes of 20-200µV. Alpha waves of the greatest amplitude are recorded from the occipital lobe region of the scalp.

**A5 Unifying Concepts and Processes: Form and Function**

Students should develop an understanding of the unifying concepts and processes of form and function.

**S06—A primary function of the cortex of the occipital lobe is the processing and storage of information related to the special sense of vision or sight. In this lesson, students examine differences in the level of alpha rhythm activity during mental arithmetic and hyperventilation compared to the control condition of eyes closed and relaxed.**

**B1 Science as Inquiry: Abilities Necessary to do Scientific Inquiry**

Students should develop an understanding of science as inquiry and develop abilities necessary to do scientific inquiry.

**S06—Students record an EEG from the occipital lobe region of an awake, resting subject under the following conditions: relaxed with eyes closed, performing mental arithmetic with eyes closed, hyperventilating (breathing quickly and deeply), and relaxed with eyes open. Students are encouraged to offer explanations for the observed EEG changes, and are encouraged to compare differences between male and female students. They are encouraged to suggest methods of exploring other factors that might account for the variability of the EEG.**

**B2 Science as Inquiry: Understandings About Scientific Inquiry**

Students should develop understandings about scientific inquiry.
—Electroencephalography used as tool to investigate functions of the human brain, like may other tools of neural science, has limited usefulness, and its usefulness depends on proper application. Based on their introductory laboratory experience with electroencephalography, students learn that answers to questions about brain function often require the application of more than one investigative tool.

D5 **Life Science: Matter, Energy, and Organization in Living Systems**

Students should develop an understanding of matter, energy, and organization in living systems.

—The cerebrum is divided into hemispheres and each hemisphere is divided into frontal, parietal, temporal, and occipital lobes. Each lobe has functions that are unique but each lobe also shares functions with other lobes.

For example, as a child, we may see (occipital lobe) a flame and touch (frontal lobe) it to see what it is like, experiencing heat and pain (parietal lobe) and remembering (temporal lobe) not to repeat the experience. These functions and others such as reasoning and abstract thought occur in the outermost part of the cerebrum called the cortex. The electrical activities of the cortex are recorded as an EEG.

**G1 Science in Personal and Social Perspectives: Personal and Community Health**

Students should be given a means to understand and act on personal and social issues, to help students develop decision-making skills, and to give students a foundation on which to base decisions they will face as citizens.

—Electroencephalography is often used in diagnostic neurology and investigative neural science. A good example is its application in the diagnosis, treatment, and study of various forms of epilepsy. The well-informed adult should be aware of both the usefulness of this diagnostic tool and its limitations in providing healthcare professionals with the information they need to minister proper care. This lesson helps students build a foundation on which to base the personal health decisions they will face as adults.

**S08 EOG: Electrooculography**

—Students investigate eye movements using temporal skin electrodes to detect and record electrical activity associated with cortical control of extra ocular muscles.

Students record horizontal eye movements and observe eye fixation and tracking. Students perform different tasks, recording and measuring the duration of saccades and fixation, and the spatial position of eye movements.

Electrooculography is the measurement and interpretation of electrooculograms (EOG), which are the electroencephalo-graphic tracings obtained while the subject, without moving the head, moves their eyes from one fixation point to another within the visual field.

A5 **Unifying Concepts and Processes: Form and Function**

Students should develop an understanding of the unifying concepts and processes of form and function.

—Students learn that binocular vision requires precisely coordinated involuntary eye movements that are initiated and controlled in the motor cortex of the frontal lobes. Coordinated control of the extra ocular muscles allows the eyes to maintain clear focus on objects that are either fixed or moving in the visual field by ensuring that light reflected from the object (pendulum, written word, etc.) falls on corresponding parts of the retinas.

B1 **Science as Inquiry: Abilities Necessary to do Scientific Inquiry**

Students should develop an understanding of science as inquiry and develop abilities necessary to do scientific inquiry.

—Students correlate electrical activity of the brain and extra ocular muscles with the performance of various visual tasks such as tracking a swinging pendulum, simulating tracking eye movement with eyes closed, reading silently, reading aloud, and reading difficult material. They measure and compare the
duration of saccades and fixation. Using their laboratory experience as a foundation, they are encouraged to ask other questions about visual control systems and to explore microsaccadic eye movement.

**B2 Science as Inquiry: Understandings About Scientific Inquiry**

Students should develop understandings about scientific inquiry.

**S08**—Students learn that the recording of electrical activity detected by skin electrodes placed lateral to the eyes can be used to study and understand visual phenomena associated with concerted eyeball movement. However, information gained through the application of electrooculography is limited, and therefore other methods of investigation must be employed to answer questions about the visual system.

**D5 Life Science: Matter, Energy, and Organization in Living Systems**

Students should develop an understanding of matter, energy, and organization in living systems.

**S08**—The visual system of the human is complex. Normal stereoscopic vision requires receptors in the retinas to convert light energy into nerve impulses which are transmitted to several parts of the brain for processing, giving us the sense of sight. Although we see with two eyes, our brain forms a single image of a three-dimensional object with a perception of depth because concerted control of the extraocular muscles allows each eye to be positioned so that light reflected from the object is focused on corresponding parts of the retinas. As we visually track the movement of an object in our visual field, the motor control system maintains this retinal correspondence while simultaneously maintaining gaze by moving the eyeballs in their orbits.

**G1 Science in Personal and Social Perspectives: Personal and Community Health**

Students should be given a means to understand and act on personal and social issues, to help students develop decision-making skills, and to give students a foundation on which to base decisions they will face as citizens.

**S08**—Electrooculography is commonly used to assess visual defects involving neuromuscular control of the eyes, such as in diagnosis and treatment success of sixth nerve palsy (paralysis of the lateral rectus). Similar eye movement/cranial nerve tests using other cardinal gazes may be employed in the diagnosis and assessment of eye disorders.

Recent applications of electrooculography involve the design of robotics, such as motorized wheelchairs and other devices that can be guided or otherwise controlled by movement of the subject’s eyes.

**S09 Biofeedback**

**A3 Unifying Concepts and Processes: Change, Constancy, and Measurement**

Students should develop an understanding of the unifying concepts and processes of change, constancy, and measurement.

**S09**—Students explore the concept of biofeedback training as a method of influencing output of the autonomic nervous system.

The autonomic nervous system (ANS) regulates visceral activities such as blood pressure and flow, gastrointestinal functions, breathing rate and depth, and so forth. Autonomic control occurs without the need for conscious input from the cerebral cortex. We do not need to think about adjusting blood pressure, for example, when we begin to exercise. The adjustment occurs automatically by way of the ANS.

A widely held belief is that ANS control of visceral function cannot be altered by conscious input, that autonomic control is essentially, and necessarily, automatic. In this lesson, students explore the concept of biofeedback training as a method of influencing output of the autonomic nervous system by measuring changes in heart rate induced through application of a biofeedback technique.

**B1 Science as Inquiry: Abilities Necessary to do Scientific Inquiry**

Students should develop an understanding of science as inquiry and develop abilities necessary to do scientific inquiry.

**S09**—Students are introduced to principles of sympathetic and parasympathetic autonomic nervous control and the concept of biofeedback training and how it can be used to study autonomic function.
Students record their ECG as an on-screen, thermometer-style heart rate display rises and falls with changes in heart rate, allowing the student to become conscious of his/her heart rate. The subject then mentally tries, without physical movement, to increase or to decrease the heart rate reading while watching the monitor.

**B2 Science as Inquiry: Understandings About Scientific Inquiry**

Students should develop understandings about scientific inquiry.

**S09**—Students learn about the basic functions and tone of the sympathetic and the parasympathetic divisions of the autonomic nervous system, and, the long-held tenant that autonomic functions are independent of the will. They experiment with biofeedback, a relatively recent clinical technique, to test the tenant and find that within limits it is possible to consciously alter autonomic tone. Based on their laboratory experience with biofeedback, students learn that newer technologies can be adapted to re-examine the validity of older hypotheses long held to be true.

Students are encouraged to think about and explore other methods of biofeedback that could prove useful in voluntarily altering autonomic tone, and to think of reasons why this might be beneficial.

**D5 Life Science: Matter, Energy, and Organization in Living Systems**

Students should develop an understanding of matter, energy, and organization in living systems.

**S09**—The human nervous system and the endocrine system control functions of all the other body systems. Students learn that nervous control involves voluntary and involuntary mechanisms, both of which serve to maintain homeostasis. Involuntary control is the domain of the sympathetic and parasympathetic divisions of the ANS.

Generally speaking, the divisions of the ANS have opposing actions controlling the function of a target organ. For example, an increase in sympathetic activity increases the heart rate; however, an increase in parasympathetic activity decreases heart rate. The two divisions work simultaneously and cooperatively to adjust visceral functions to meet body needs according to changes in the internal and external environment.

**G1 Science in Personal and Social Perspectives: Personal and Community Health**

Students should be given a means to understand and act on personal and social issues, to help students develop decision-making skills, and to give students a foundation on which to base decisions they will face as citizens.

**S09**—Mental or psychological stress increases sympathetic activity and decreases parasympathetic activity, resulting in an increase in heart rate, an increase in blood pressure, reduced gastrointestinal functions, and so forth. Over the short term, these changes may be beneficial, but when they are prolonged or become chronic, they become detrimental and can cause disease. Using heart rate biofeedback techniques, an affected person can be taught to relax and to increase parasympathetic tone and thus reduce sympathetic activity, evidenced by a decrease in heart rate. Initially, a machine monitors heart rate and provides the feedback signals that help the subject develop voluntary control. Eventually, the subject is able to recognize and control reactions to stress on his own by recalling and eliciting the same relaxed state of mind used in the biofeedback laboratory when he is at home or at work. Relaxation training using biofeedback has been successfully applied to the management of asthma, cerebral palsy, hypertension, migraine headache, irritable bowel syndrome, and numerous other maladies.

**S10 Aerobic Exercise Physiology**

**A3 Unifying Concepts and Processes: Change, Constancy, and Measurement**

Students should develop an understanding of the unifying concepts and processes of change, constancy, and measurement.

**S10**—Students record their electrocardiogram and heart rate at rest and during and after a specific set of dynamic exercises. Students measure changes in the electrocardiogram and heart rate and see how they change to meet the metabolic demands of physical exercise.

**A5 Unifying Concepts and Processes: Form and Function**

Students should develop an understanding of the unifying concepts and processes of form and function.
S10—Students learn that a regular program of physical exercise increases skeletal muscle size and promotes the growth of blood vessels that supply oxygen and nutrients to the muscle and remove metabolic wastes. The adaptations and physiological changes that develop during chronic exercise generally result in an increased ability of the muscle to perform work at greater levels of intensity, and an increased capacity to work at any given level for a longer period of time before fatiguing. A Physically fit person tends to have a lower heart rate at rest and immediately after moderate exercise than does an unfit person.

B1 Science as Inquiry: Abilities Necessary to do Scientific Inquiry
Students should develop an understanding of science as inquiry and develop abilities necessary to do scientific inquiry.

S10—Students learn that physical fitness can be assessed by measuring changes in heart rate associated with a specific set of dynamic exercises, such as performing jumping jacks, running in place, or stepping up and down in place. Students record the resting ECG and heart rate, the exercise ECG and increase in heart rate at the immediate end of an exercise period, and the time it takes from the end of the exercise period to the return of resting ECG and heart rate. They compare measured values with normalized data based on gender, age, and body weight. They compare performance levels between groups, such as young women vs. young men, or persons with body weight 75 – 150 lbs. vs. persons with body weight 151 – 250 lbs.

G1 Science in Personal and Social Perspectives: Personal and Community Health
Students should be given a means to understand and act on personal and social issues, to help students develop decision-making skills, and to give students a foundation on which to base decisions they will face as citizens.

S10—Physiological adaptations to chronic exercise, initiated by even the most modest physical activity, play a major role in the prevention of obesity, hypertension and other cardiovascular diseases, respiratory disease, adult-onset (type II) diabetes, and other maladies associated with sedentary lifestyles. This lesson helps make students aware of the value and the need as adults to maintain a healthy lifestyle that includes regular exercise.

S11 Reaction Time

A3 Unifying Concepts and Processes: Change, Constancy, and Measurement
Students should develop an understanding of the unifying concepts and processes of change, constancy, and measurement.

S11—Students measure reaction times and see how easily and rapidly a person learns, as demonstrated by his/her ability to anticipate when to press a button in response to an audible signal. As a person learns what to expect, reaction time typically decreases.

Reaction time is the interval between when a stimulus is presented and when the response to the stimulus occurs. Learning, the acquisition of knowledge or skills due to experience and/or instruction, can alter reaction time in some stimulus-response situations.

A5 Unifying Concepts and Processes: Form and Function
Students should develop an understanding of the unifying concepts and processes of form and function.

S11—Students learn that the ability to either involuntarily or voluntarily respond to a stimulus is dependent on a reflex or stimulus-response pathway.

Physiologically, a reflex, or a stimulus-response begins with the application of a stimulus to a sensory receptor, such as an auditory hair cell, and ends with a response by an effector, such as a skeletal muscle.

Anatomical elements of the pathway include a sensory receptor, a sensory or afferent neuron, an integrating center in the brain or spinal cord, a motor or efferent neuron, and an effector.

B1 Science as Inquiry: Abilities Necessary to do Scientific Inquiry
Students should develop an understanding of science as inquiry and develop abilities necessary to do scientific inquiry.
S11—Students measure and compare reaction times of an individual subject using two stimulus presentation schedules: fixed intervals, and pseudo-random intervals. Students are introduced to elements of statistics and their application in data analysis, and use statistics to determine the effects of learning on reaction times. They discover that when pseudo-random presentation trials are repeated, it takes longer for reaction times to decrease and the decrease is less than as occurs with fixed-interval presentation.

B2 Science as Inquiry: Understandings About Scientific Inquiry
Students should develop understandings about scientific inquiry.

S11—Students take a relatively simple look at reaction time and how changing one variable, stimulus presentation interval, can result in differences in reaction time.

Students realize that other factors could influence reaction time and are encouraged to think about and explore them using their laboratory experience. For example, a person’s reaction time could be measured and compared in two different conditions, such as reading a book vs. watching TV.

D5 Life Science: Matter, Energy, and Organization in Living Systems
Students should develop an understanding of matter, energy, and organization in living systems.

S11—Students learn that a reflex is an involuntary or automatic, programmed motor response to a sensory stimulus. Literally, the word reflex is derived from a term meaning to reflect, or return back, with reference to the direction of travel of first the sensory impulses and then the motor impulses along the reflex pathway. Touching a hot object and jerking the hand away, or stepping on a tack and lifting the injured bare foot are examples of simple human reflexes. Reflexes in animals represent the earliest organization of neurons into a functional unit. Even in adult animals that lack a brain, such as a jellyfish, neurons have become specialized and organized to provide for simple, often life-preserving, reflex responses. In the human, reflex activities appear about five months before birth. Reflexes allow the body to react automatically and involuntarily to a variety of internal and external stimuli so as to maintain homeostasis.

A stimulus-response is functionally similar to a reflex except that it is voluntary rather than involuntary, and as such, it can be learned and is subject to behavioral modification. An example is lifting a finger in response to an audible click.

G1 Science in Personal and Social Perspectives: Personal and Community Health
Students should be given a means to understand and act on personal and social issues, to help students develop decision-making skills, and to give students a foundation on which to base decisions they will face as citizens.

S11—Usually, longer reaction times are a sign that the person is paying less attention to the stimulus and/or is processing other information. For example, if you took more time to respond to audible clicks while also reading a book than when you were also watching TV then you could infer that you were probably paying more attention to the book than to the TV since your brain took longer to respond.

Assessments from simple reaction time tests allows researchers a glimpse into the cognitive and neurological functioning of people as they perform tasks. Of current topical interest is the question of whether concurrent use of cell phones while driving an automobile impairs judgment and slows the driver’s reaction time.

S12 Respiration: Apnea

A3 Unifying Concepts and Processes: Change, Constancy, and Measurement
Students should develop an understanding of the unifying concepts and processes of change, constancy, and measurement.

S12—Two principle functions of the human respiratory system are to supply oxygen to the blood and remove carbon dioxide from the blood. When the body is at rest, the rate and depth of breathing is stable and matches the body’s needs for oxygen absorption and carbon dioxide removal.

Students learn that blood levels of carbon dioxide influence the rate and depth of breathing. When blood carbon dioxide increases above resting levels, as during physical exercise or after breath-holding, the rate
and depth of breathing increases. When blood carbon dioxide decreases below resting levels as a result of voluntary hyperventilation or over-breathing, respiratory rate and depth decrease. Students record and measure changes in respiratory rate and depth associated with induced changes in blood carbon dioxide.

**A5 Unifying Concepts and Processes: Form and Function**

Students should develop an understanding of the unifying concepts and processes of form and function.

**S12**—The human lungs occupy air-tight compartments within the thorax or chest. Students learn that contraction of chest muscles increases volume of the thorax and lungs which results in air pressure inside the lungs falling below atmospheric pressure and air moving into the lungs. These events characterize inspiration.

Expiration, or the exhaling of air from the lungs occurs at rest when inspiratory muscles relax, decreasing the volume of the lungs and the thorax, thereby increasing pressure within the lungs above atmospheric pressure, forcing air out of the lungs.

**B1 Science as Inquiry: Abilities Necessary to do Scientific Inquiry**

Students should develop an understanding of science as inquiry and develop abilities necessary to do scientific inquiry.

**S12**—Students observe and record EMGs (electromyograms) from thoracic respiratory skeletal muscle during eupnea, or normal unlabored breathing at rest. Changes in the EMG are associated with modifications in the rate and depth of the respiratory cycle that occur before, during, and after periods of apnea vera and voluntary apnea (cessation of breathing). Students compare changes in the EMG associated with apnea to the EMG recorded during eupnea.

**B2 Science as Inquiry: Understandings About Scientific Inquiry**

Students should develop understandings about scientific inquiry.

**S12**—Students use respiratory electromyography to study changes in respiratory rate and depth associated with changes in blood carbon dioxide. They learn that electromyographic methods allow only for qualitative assessment of the changes. Quantitative measurements of changes in respiratory cycle depth and more exact measurements of changes in respiratory rate require the application of more sophisticated technology and analytical techniques. Thus, the results obtained from scientific inquiry are limited by the nature of the applied methods.

**D5 Life Science: Matter, Energy, and Organization in Living Systems**

Students should develop an understanding of matter, energy, and organization in living systems.

**S12**—Students learn that all living cells of the body require oxygen to derive energy from food. Stored chemical energy is used by cells to perform work. Cells produce carbon dioxide as a waste product of metabolism. The respiratory system works in conjunction with the circulatory system to deliver oxygen to the cells and remove carbon dioxide.

**G1 Science in Personal and Social Perspectives: Personal and Community Health**

Students should be given a means to understand and act on personal and social issues, to help students develop decision-making skills, and to give students a foundation on which to base decisions they will face as citizens.

**S12**—The normal person exhales carbon dioxide as fast as the body produces it so that blood carbon dioxide remains within normal limits. In diseases or conditions in which a person subconsciously hyperventilates, such as in chronic anxiety states, blood carbon dioxide may fall too low, removing the main stimulus to breathe, resulting in temporary apnea, dizziness, and fainting. Anxiety states are common in contemporary cultures.

On the other hand, if blood carbon dioxide is permitted to rise above normal, as would occur if a child held his breath to spite his parents, the elevated carbon dioxide would soon become a too powerful stimulus for the brain to ignore and breathing would automatically resume.
Answer Guides

- The answers have been removed from this online review copy but are included on the installation CD for each *Biopac Science Lab* system.
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