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Chapter 1: Introduction to LabScribe and the ETH-256

Overview

A brief explanation of the ETH-256NI controls are presented below. For more a detailed explanation and troubleshooting assistance, consult the hardware appendix at the end of this manual.

Front Panels and Controls

The ETH-256 is divided into two identical functional units (Figure 1-1 on page 1) both are able to make low-noise, AC-coupled recordings of bioelectric potentials or DC-coupled transducer recordings. Four knobs control each channel. Their functions are described below.

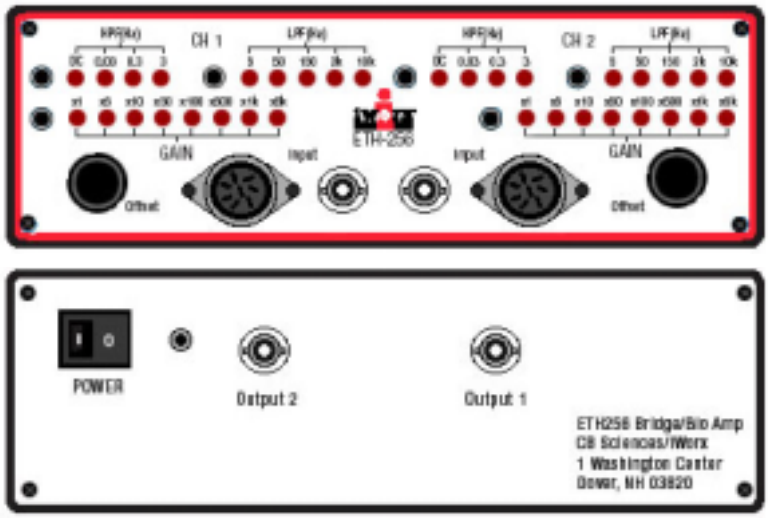

Figure 1-1: A diagram of the front (upper) and rear (lower) of ETH-256

High Pass (Hz)

The High Pass (Hz) switch is used to select the function of the channel. It has four positions. The DC position DC couples the input for measurement from transducers or other sensors such as pH electrodes or Ion Selective Electrodes (ISEs). There are three high pass filter settings: 0.03 for ECG, 0.3 for ECG or EEG and 3.0 for EMG. The higher the value of the AC coupling filter, the more signal contributions from body movement or breathing are removed.

Offset

In any high pass position, the offset knob can be used to move the displayed signal up or down on the computer screen

Gain

Gain allows small signals to be made larger before going to the recording unit.

Low Pass (Hz)

The low pass control is used to adjust the amount of noise seen on the baseline of your recording. In general, the lower the filter value, the quieter the trace will appear, and the less able it will be to view rapidly changing events.

Rear Panel and Connectors

All of the input and output connectors for the ETH-256 are located on the rear panel (Figure 1-1 on page 1).

Input

Use this connector to connect the transducer or biopotential pod.

Output

The output BNC connector contains the output signal. It must be connected to your recorder for the signal to be visible on the computer screen

The LabScribe software traditionally resides in a folder in the Program Files folder on the computer s hard drive. The software permits electrical signals to be displayed on the computer screen in a format that resembles a laboratory strip chart recorder. Each peripheral device may produce signals of a different size and duration. Therefore, you need to be able to make adjustments to the software so that the signals are the appropriate size and shape on the screen. In the tutorial that follows you will learn how to make these adjustments and how to make simple measurements from traces.

In future experiments you will open the software and find that many recording parameters have been set for you. This will permit you to collect data quickly and efficiently, making only minor adjustments to

obtain the best response. Over time you may forget how to perform certain tasks. You can refresh your memory by referring to this tutorial or to the User s Manual, which describes additional features of the unit and software that are not covered here.

Experiment 1: This is LabScribe“ - A Tutorial

LabScribe allows data to be accumulated, displayed and analyzed on a computer screen in a format similar to a laboratory strip chart recorder.

Equipment Setup

Connect the ETH-256 and the computer:

1. Place the ETH-256 unit on the bench, close to the computer.
2. Use the shielded cable with the four-input breakout box provided and connect it to the National Instruments Analog to Digital converter card (NI-A/D card) in your computer. The NI-A/D card must be properly installed and have a NIDAQ assigned device number.
3. Connect the output of channels one and two on the rear panel of the ETH-256 to the input BNC s labeled Ch1 and Ch 2 on the provided breakout box.
4. Insert the power plug into the rear of the ETH-256 unit and the transformer into the electrical outlet. Confirm that the red power LED is illuminated.

Start the Software

1. Click the (Windows) Start menu, move the cursor to Programs and then to the iWorx folder and select LabScribe.
2. When the program opens, select Load from the Settings menu.
3. When the dialog box appears select NI Animal and then click OK.
4. Click on the Settings menu again and select the Tutorial settings file.
5. After a short time, LabScribe will appear on the computer screen with the Tutorials settings (Figure 1-2 on page 4).

The LabScribe software has five windows:

¥ Main record incoming signals and perform data analysis.

¥ Analysis perform data analysis.

¥ Journal type and insert recordings to construct a lab report.

¥ Marks review typed annotations entered during data accumulation.

¥ Preview examine incoming signals without recording.

The Main window is displayed when the application is first opened. Notice that each of the channels has its own (white) recording area, with a title area (above) containing a title, AutoScale and FullScale select buttons, and the voltage value. Above the channel one title area is a time value, the sampling speed, the display time, the mark comments, and the Start button.

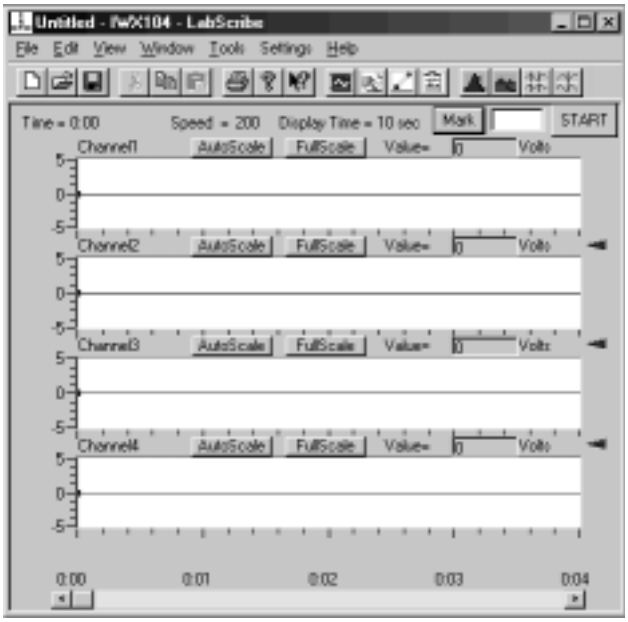

Figure 1-2: The LabScribe Window

Recording with LabScribe

The Signal

The output from a plethysmograph will be used as a signal source.

Proceed as follows:

1. Locate the DIN 8 plug on one end of the plethysmograph cable; insert it carefully into the DIN input on channel one (Figure 1-3 on page 5).
2. Locate the plethysmograph on the other end of the cable. Place the unit on the volar surface (where the fingerprints are located) of the distal segment of a middle finger; wrap the Velcro to attach the unit firmly to the end of the finger.

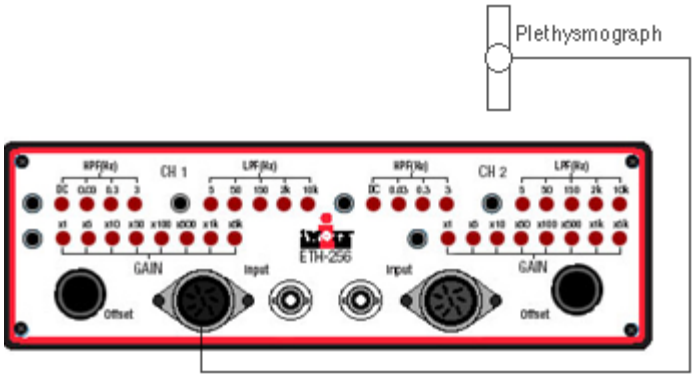

Figure 1-3: The connection between the plethysmograph and the ETH-256

3. Set the controls on the ETH-256 (Figure 1-1 on page 1) as follows

	Ch. 1: Plethysmograph	Ch. 2: No Device
Gain	X10	x1
High Pass	DC	DC
Low Pass	50Hz	50Hz

Recording with LabScribe

The size of the signal:

1. Click Start (Figure 1-2 on page 4) and record the finger pulse.
2. Click AutoScale in the channel one title area and see the rhythmic signal get bigger. Possible problem: If the NI card and computer are not communicating there will be a sine wave in all four recording windows. If this happens, stop recording and select Preferences under the Edit menu. Confirm that the NI card option is selected and that the proper device number has been entered.

3 Click Stop to halt recording. Click and drag the red arrow (in the right margin of the window) up and down to make the channel one recording window as large or small as desired.

The screen time:

The default value for the time for a signal to cross the screen is 10 seconds this value is displayed as Display Time in the area above the channel one title line (Figure 1-2 on page 4). The screen time can be changed by clicking the display controls in the toolbar (Figure 1-4 on page 6).

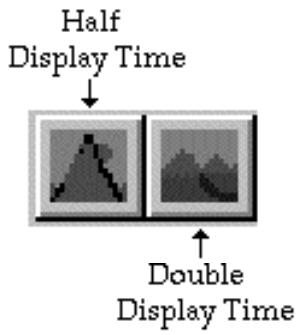

Figure 1-4: The display icons in the tool bar.

Demonstrate this as follows:

1 Click the left icon (big mountain) and notice that the trace spreads out the Display Time is 5 seconds.

2 Click the right icon (small mountains) twice and see that the rhythmic peaks get closer the Display Time is 20 seconds.

3 Click the left icon once to return to a Display Time of 10 seconds.

The sampling rate:

The default value for the number of samples taken per second is 200 this value is displayed as speed in the top left margin above the channel recording windows. While this value is acceptable for most experiments, it can be changed by selecting Preferences in the Edit menu and adjusting the sampling rate. Such a change does not change the screen time.

Saving a LabScribe File

It is wise to save work in any computer application, and LabScribe is no exception:

1. Click on the File menu and select Save As.
2. When the standard panel appears, type a meaningful name. Click Save to save the file(.iwd) to a known destination (e.g. the Desktop) on the computer.

Making Marks on a Record

Many experiments are divided into a series of exercises. It is convenient to annotate each exercise, so that during subsequent review of your data file it is possible to determine what was done at any particular stage. This will be done by typing (the comment appears in the Marks area next to Start, see Figure 1-2 on page 4) on the keyboard and pressing the Enter key.

Marks can be entered in two ways:

Entering Marks when not recording Notice that when data have been recorded, two blue vertical lines or cursors overlay the screen. As you will discover later, these can be used to make measurements. However, if you type a comment on the keyboard and press the Enter key, the mark will be entered in the lower margin at the left cursor.

Entering Marks while recording Marks can be entered on-the-fly when data are being recorded:

1. Click Start.
2. Type my first comment on the keyboard and notice that the words appear in the Marks area to the left of Start.
3. Press the Enter key on the keyboard and notice that
   - ¥ the words disappear
   - ¥ a vertical line appears in the LabScribe window.
4. Type my next comment repeat step #3.

5 Repeat to enter a total of five different comments, pressing Enter after each.

6 Click Stop.

7 Select Save in the File menu to update your file.

The last mark may be seen in the lower margin of the recording window.

Data Analysis of your LabScribe File

While data analysis may be performed during the lab session, your file can be stored on a floppy disk or on a hard drive. The file can be opened using a compatible version of the LabScribe software; the National Card is not required for data analysis.

Data analysis can be done in the Main or the Analysis window. Access to these windows can be gained either through the Windows menu or by clicking on the appropriate icon (Figure 1-5 on page 8).

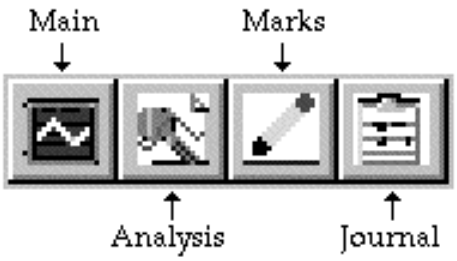

Figure 1-5: The Windows icons in the toolbar.

Data Analysis in the Main Window

Navigating the Main Window

There are two ways to navigate around a data file in the Main window, the Marks option and the scroll bar.

Scrolling

1 Move the cursor to the scroll bar in the lower margin.

2 Click the arrows to scroll the screen to the left or right; notice the typed marks in the lower right margin.

Marks

1. Click in the Windows menu and select Marks, or click in the Marks icon in the toolbar (Figure 1-5 on page 8). Either procedure will display a panel with the typed comments, which may be modified at this stage.
2. Click on the time and then GoTo.
3. The panel will disappear and the relevant portion of data will be displayed in the center of the recording window.

Notice Marks can be moved vertically and placed anywhere in the recording by clicking and dragging the mouse. Marks in a given view can be reset by electing Reset Marks under the View menu.

Making Measurements in the LabScribe Window

Measurements are taken using the cursors, which are vertical lines that address all channels and can be called using one of the cursor icons (Figure 1-6 on page 9).

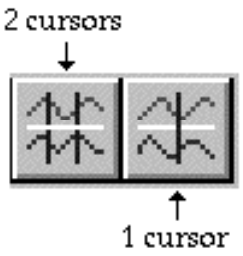

Figure 1-6: The cursor icons in the tool bar.

Using a Single Cursor

1. Click the right cursor icon, with a single vertical bar a (blue) vertical line appears over the recording window with a star where the bar intersects each trace.
2. Click and drag the line to the left or right to make measurements of:

¥ the absolute time from the beginning of the trace shown in the top left margin, above the channel one title area.

¥ the absolute voltage displayed in the voltage value area on the right of the channel title area.

Using Two Cursors

1. Click the left cursor icon, with two vertical bars two (blue) vertical lines appear over the recording window, one with a star and the other with a square where the bar intersects the trace (Figure 1-7 on page 10).

2 Click and drag either or both lines to the left or right to display the difference in:

¥ time shown in the top left margin, above channel one.

¥ the voltage displayed in the value area on the right, above each channel recording window.

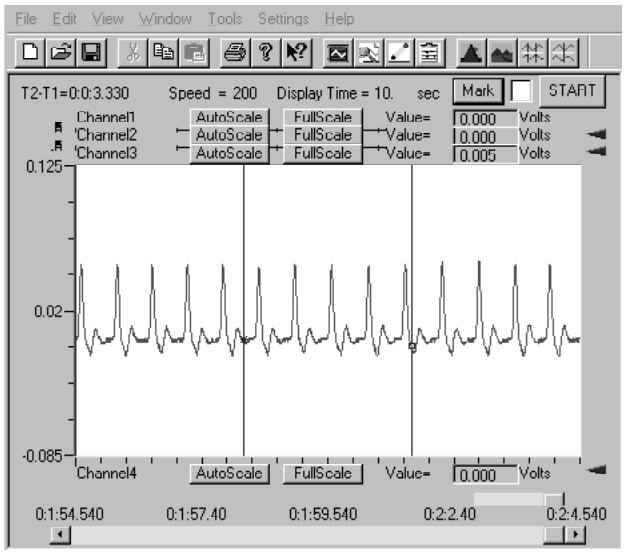

Figure 1-7: A finger pulse recorded in the Main window.

The Journal

The Journal can be used as a notebook and as a means to construct a lab report. It is possible to copy (Edit menu) a screen of data, open the Journal (Windows menu or click the icon (Figure 1-5)), and Paste (Edit menu). Return to the Main window either through the Windows menu or by clicking on the Main icon.

Data Analysis in the Analysis Window

Additional data analysis features are available through the Analysis window (Figure 1-8 on page 11), which will open only when a region of data in the Main window has been selected using two cursors (Figure 1-6 on page 9). The data displayed are the sample points between the two cursors.

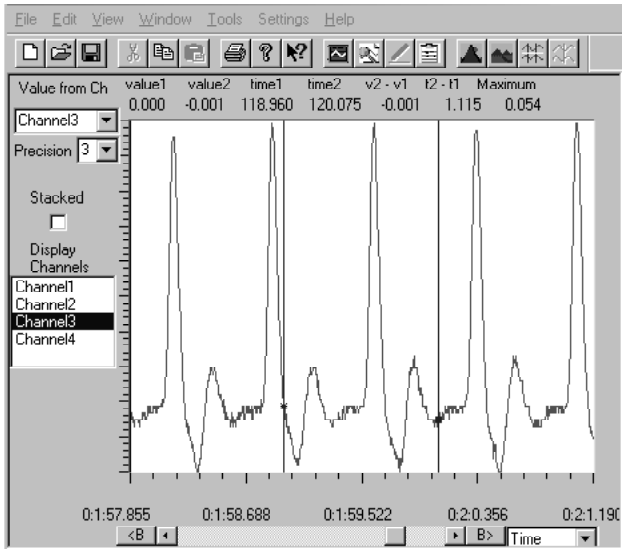

Figure 1-8: A finger pulse recorded in the Analysis window.

1 Click the left cursor icon, with two vertical bars (Figure 1-6 on page 9) two blue vertical lines appear over the recording window.

2 Drag the cursors left and right until a region of interest is located between the two blue lines.

3 Open the Analysis window by either:

¥ selecting Analysis from the Windows menu.

¥ clicking the Analysis icon (Figure 1-5 on page 8).

Channel Display

All available channels are displayed under one another. To change this:

¥ click to de-select 1, 2 or 3 channels from the display channels list at the left.

¥ click to stack or superimpose the remaining channels in the Analysis window.

1 Find the list of channels displayed.

2 Click to de-select all but channel one the one with your finger pulse.

Screen Display

The Display time can be changed in increments of two as in the Main window (Figure 1-2 on page 4) and the trace can be scrolled horizontally in the Analysis window using the arrows in the lower margin.

Data Values

The cursors can be moved horizontally by clicking and dragging to the left or right. Data values for any one channel are displayed in the upper margin of the Analysis window. The channel analyzed can be changed by clicking the appropriate selection in the pop-down menu in the upper left margin, and the accuracy of the values (number of decimal places) can be set by changing the Precision setting.

The upper margin displays values for voltage and time for each cursor, their difference, and the maximum, minimum and mean values. The titles or data can be copied into the Journal by right clicking the mouse in the data display area of the analysis window and selecting the Add Data/Titles to Journal item.

1. Move the cursor so that the symbol on each is located on adjacent peaks of your finger pulse record.
2. Read off the time difference (t2 - t1) between the two cursors.
3. What is your heart rate (60/(t2 - t1))?
4. Right mouse click in the Analysis window and select:

   ¥ add titles to Journal.

   ¥ add data to Journal.
5. Select Copy (Edit menu), open the Journal (Windows menu or click the icon (Figure 1-5 on page 8)), and Paste (Edit menu).
6. Return to the main window

As in the Main window, the record can be copied and pasted directly into the Journal, displaying the Marks and the trace with only a portion of the horizontal axis.

Channel Features

Raw data can be displayed on all channels, and data manipulations like setting units and inverting the trace can be achieved by a right mouse click before or after recording. In addition, a right mouse click on the recording window of channels two, three or four displays either a rate or an integral of the data in channels one, two and three, respectively. This can be demonstrated by integrating the finger pulse signal to display the blood flow through the finger:

1. Place the cursor over channel two, right click the mouse and select Integrate.
2. Click the left cursor icon, with two vertical bars (Figure 1-6 on page 9) two blue vertical lines appear over the recording window.

3 Drag the cursors left and right until a region of interest is located between the two blue lines.

4 Open the Analysis window by either:

¥ selecting Analysis from the Windows menu.

¥ clicking the Analysis icon (Figure 1-5 on page 8).

5 Your data may look like Figure 1-9 on page 13.

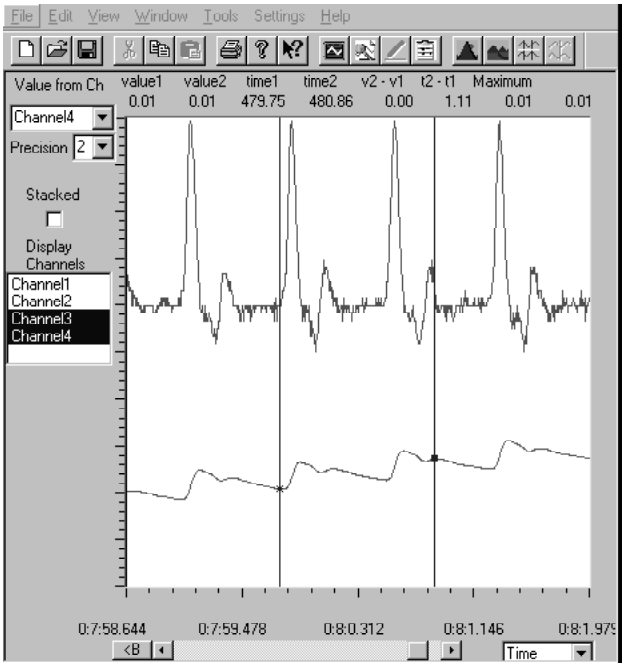

Figure 1-9: Finger pulse (upper trace) and its integral (lower trace) in the Analysis windows.

Chapter 2: Cardiovascular Physiology

Overview

The heart is a pump that pushes blood around the body. Blood enters the heart at a low pressure and leaves at a higher pressure; it is this high arterial pressure that provides the energy to force blood through the circulatory system. Figure 2-1 on page 15 shows the organization of the human heart and the circulatory system. Blood returning from the body is sent to the right side of the heart and then to the lungs to pick up oxygen and release carbon dioxide. This oxygenated blood is then sent to the left side of the heart and back to the body, where oxygen is liberated and carbon dioxide is collected. The complete division of the heart insures that there is no mixing of deoxygenated blood (in the right side) with oxygenated blood (in the left side).

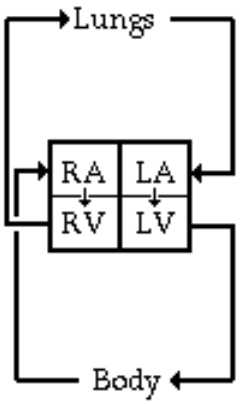

Figure 2-1: A diagram to show the circulation of blood around the human body and its association with the heart, composed of a right atrium (RA), a left atrium (LA), a right ventricle (RV), and a left ventricle (LV).

The mammalian heart is autorhythmic, since it will continue to beat if removed from the body (and kept in an appropriate solution). Heart contractions are, therefore, not dependent upon the brain, rather the rhythm comes from within the heart itself. The heart is composed almost entirely of large, strong muscle fibers, which are responsible for the pumping action of the heart. Other cardiac

muscle cells are weakly contractile and produce the rhythm for, and conduct it to, the rest of the heart. A group of these weak muscle cells is located in the sinoatrial (SA) node (Figure 2-2 on page 16) and acts as the pacemaker for the heart. These cells rhythmically produce action potentials which spread via gap junctions to fibers of both atria. The resulting contraction pushes blood into the ventricles. While adjacent atrial fibers are connected by gap junctions, the only electrical connection between the atria and the ventricles is via the atrioventricular (AV) node (Figure 2-2 on page 16). The action potential spreads slowly through the AV node and then rapidly through the Bundle of His and Purkinje fibers to excite both ventricles.

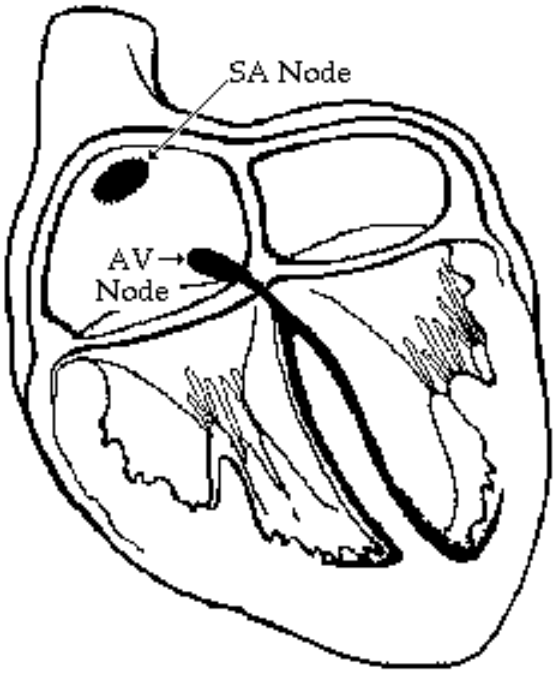

Figure 2-2: A diagram of the human heart to show the location of the sinoatrial (SA) and atrioventricular (AV) Nodes.

The semilunar valves are located between the ventricle and the artery on each side of the heart. In the relaxed heart the high arterial pressure shuts the semilunar valves and prevents blood flow from the artery into the ventricle. Ventricular contraction increases the pressure of the blood in the ventricle. When the ventricular pressure is greater than the arterial pressure, the semilunar valves open and blood flows into the artery. The myocardium then relaxes, the ventricular pressure declines and the semilunar valves close.

Experiment 2: Electrocardiogram and Heart Sounds

Overview

The cardiac cycle involves a sequential contraction of the atria and the ventricles. The combined electrical activity of the different myocardial cells produces electrical currents that spread through the body fluids. These currents are so large that they can be detected by recording electrodes placed on the skin. In this lab you will attach three electrodes to a student volunteer. These electrodes will be connected to the ETH-256 and the signal will be displayed on the computer screen in a strip chart format. The regular pattern of peaks produced by each heart beat cycle is called the electrocardiogram or ECG (Figure 2-3 on page 17).

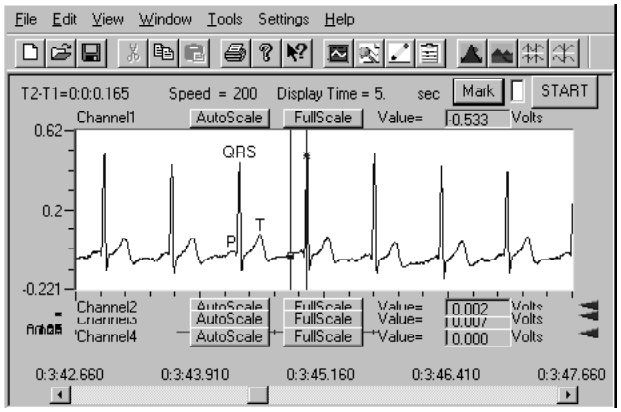

Figure 2-3: ECG trace in the Main window showing the P, QRS, and T waves; the cursors are positioned to measure the amplitude (in volts) of the QRS wave.

The action potentials recorded from atrial and ventricle fibers are different from those from nerves and skeletal muscle. The cardiac action potential is composed of three phases: a rapid depolarization, a plateau depolarization (which is pronounced in ventricular fibers), and a repolarization back to resting membrane potential. The components of the ECG (Figure 2-3 on page 17) can be correlated with the electrical activity of the atrial and ventricle fibers such that:

¥ the P-wave is produced by atrial depolarization

¥ the QRS complex is produced by atrial repolarization and ventricle depolarization

¥ the T-wave is produced by ventricle repolarization.

In this lab you will record the ECG from a volunteer. You will listen to the characteristic lub-dup heart sounds. The lub sound occurs during the early phase of ventricle contraction and is produced by closing of the atrioventricular valves, which prevents blood flow into the atria. When the ventricles relax the blood pressure drops below that in the artery and the semilunar valves close, producing the dup sound.

Equipment Required

PC computer

ETH-256 and National Instruments A/D Card

ECG cables and gray ECG unit

Alcohol swabs

Stethoscope

Event marker

Alcohol swabs

Equipment Setup

1 Connect the ETH-256 unit to the A/D card (described in Chapter 1).

2 The volunteer should remove all jewelry from their wrists and ankles.

3 Use an alcohol swab to clean and abrade a region of each wrist which has little or no hair.

4 Remove the plastic disk from a disposable electrode and apply the electrode to the abraded area on one wrist. Repeat for the other wrist and one ankle.

5 Attach the cable from the ECG pod unit to channel one on the ETH-256.

6 Attach one end of each of the three electrode cable to the pod unit and snap the other ends onto the disposable electrodes, so that:

¥ The + lead is attached to the right wrist

¥ The - lead is connected to the left leg

¥ The ground or reference lead is connected to the left wrist.

7 Use the DIN8 plug to connect the event marker to channel two (Figure 2-4 on page 19).

8 Set the controls on the ETH-256 as follows:

	Ch. 1: ECG pod	Ch. 2: Event Marker
Gain	x10	x1
High Pass	0.3 Hz	DC
Low Pass	50Hz	50Hz

9 The volunteer should sit quietly with their hands in their lap.

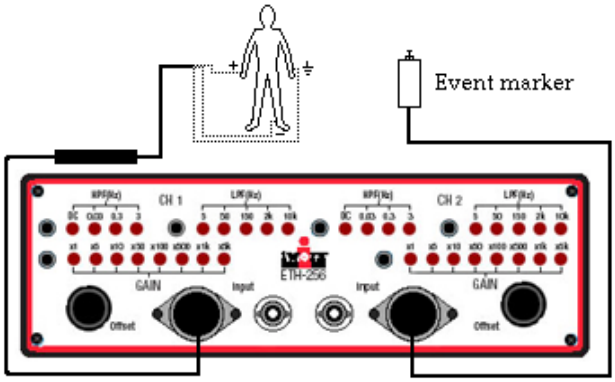

Figure 2-4: The equipment used to measure the ECG from a volunteer.

Start the Software

1 Click the (Windows) Start menu, move the cursor to Programs and then to the iWorx folder and select LabScribe.

2 When the program opens, select Load from the Settings menu.

3 When the dialog box appears, select Human and then click OK.

4 Click on the Settings menu again and select the Heart #1 settings file.

5 After a short time, LabScribe will appear on the computer screen with the Heart #1 settings.

Exercise 1: ECG in a Resting Volunteer

Aim: To measure the ECG in resting individuals.

Procedure

1 Click Start and the click AutoScale in the channel one title area and see the rhythmic ECG signal.

¥ If the trace is upside down (QRS goes down) click Stop and switch the positive and negative electrodes.

¥ If a larger signal is required, the electrodes should be moved from the wrists to the skin immediately below each clavicle.

2 Have the volunteer open and close their fists, or move their arms across their chest. Notice that the trace moves around the screen and the ECG is distorted. This should tell you that it is necessary to keep still and relaxed when recording the ECG.

3 When you have a suitable trace type "*** s resting ECG" (where *** is the volunteer s name) and press Enter on the keyboard.

4 Click Stop to halt recording; your data may look like Figure 2-3 on page 17.

5 Select Save As in the File menu, type a meaningful name and save the file in an appropriate place on the hard drive.

Data Analysis

1 Click the 2 cursor icon (Figure 2-5 on page 20), so that two blue vertical lines appear over the recording window.

2 Drag the cursors left and right so that four heart beat cycles are located between the two blue lines.

3 Click the Analysis icon (Figure 2-5 on page 20) to open the Analysis window.

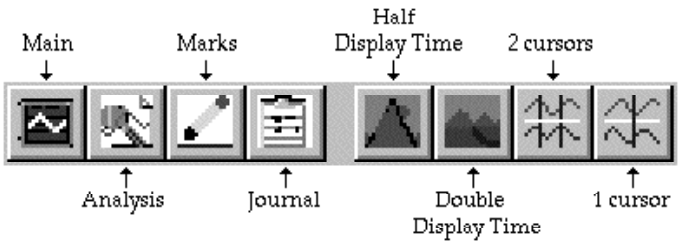

Figure 2-5: The LabScribe toolbar

4 Click to de-select channel two, to display only the ECG trace.

5 Use the mouse to click and drag the cursors around the Analysis window to measure:

¥ the amplitude (Max-min) of three QRS waves (shown in Figure 2-1).

¥ the amplitude (v2-v1) of three P waves.

¥ the amplitude (v2-v1) of three T waves.

¥ the time interval (t2-t1) between four adjacent QRS waves (you should have three values). Remember the display time can be changed in increments of two (as in the Main window) to expand the horizontal axis and obtain a very accurate time measurement and the trace can be scrolled horizontally using the arrows in the lower margin.

6 Data should be entered into the Journal either by typing the values directly, or by typing a title and then transferring the title and then each data set by right clicking in the Analysis window.

7 Calculate (and type your results in your Journal):

¥ the average value for the amplitude of the P wave, the QRS wave, and the T wave.

¥ the average time interval (in seconds) between adjacent QRS waves and then calculate the heart rate as follows:

$$\text{Heart rate} = \frac{60 \text{ beats/minute}}{\text{mean time interval (s)}}$$

Questions

1 Is the amplitude of the different waves the same in different cardiac cycles?

2 Which wave has the largest amplitude?

3 What is the heart rate?

Exercise 2: ECG Recordings from other Students

Aim: To measure heart rate from all students.

Procedure

1 Disconnect the leads from the volunteers wrists and ankle and place them on a second student. Record their ECG as above (omit step #2).

2 Repeat until all students have recorded their ECG.

Data Analysis

Make measurements as outlined above.

Questions

1 Is the amplitude of the different waves the same in different individuals? Why?

2 For each individual which wave has the largest amplitude? Is this result the same for all individuals?

3 Is the heart rate the same for each individual?

4 What variation is there within the class?

5 Is there any obvious correlation between heart rate and sex, apparent fitness, diet?

Exercise 3: ECG and Heart Sounds

Aim: To measure the ECG in resting individuals.

Procedure

1. The operator should place the head of the stethoscope on the left side of the volunteer s chest and listen for the heart sounds. Move the stethoscope head to different positions until clear heart sounds are heard.
2. The operator should click Start and, holding the stethoscope head in one hand and the event marker in the other, press the event marker on lub and release on dup.
3. After a few heart beat cycles, click Stop to halt recording.
4. Select Save in the File menu.

Data Analysis

Your data may look like Figure 2-6 on page 23.

1. Click the 2 cursor icon (Figure 2-5 on page 20), so that two blue vertical lines appear over the recording window.
2. Drag the cursors left and right so that one heart beat cycle is located between the two blue lines.
3. Click the Analysis icon (Figure 2-5 on page 20) to open the Analysis window.
4. Use the mouse to click and drag one cursor to measure the time delay (t2-t1) between:

¥ the peak of the QRS wave and the lub sound.

¥ the peak of the T wave and the dup sound.

5. Data should be entered into the Journal either by typing the values directly, or by typing a title and then transferring the title and then each data set by right clicking in the Analysis window.
6. Copy the trace and paste it into the Journal.
7. Repeat the above measurements with at least three other cardiac cycles.

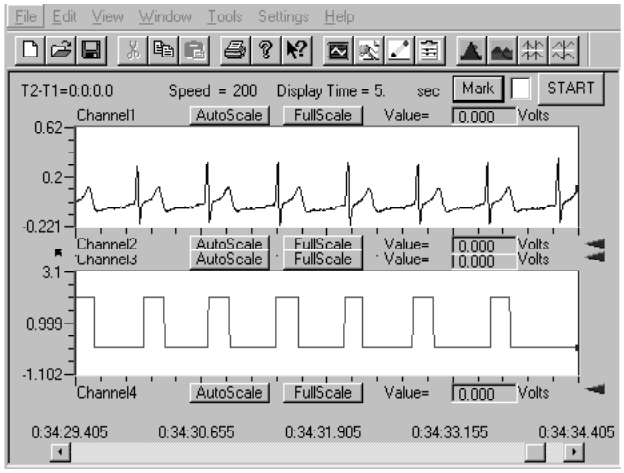

Figure 2-6: An ECG (upper trace) correlated with heart sounds (lower trace).

Questions

1. Why is the lub sound recorded around the peak of the QRS wave?
2. Is the time delay between the QRS wave and the lub sound always the same? Should it be, and why is it not?
3. Why is the dup sound recorded around the peak of the T wave?
4. Is the time delay between the T wave and the dup sound always the same? Should it be, and why is it not?

Experiment 3: Electrocardiogram and Peripheral Circulation

Overview

The arterial system functions as a pressure reservoir. Blood leaves the arterial system continuously through the capillaries, but enters intermittently from the heart. When the ventricles contract (called systole) the semilunar valves open and blood passes into the arterial system. At this point the arteries expand and the blood pressure increases the maximum value is called the systolic pressure. The heart then relaxes (called diastole), fills with blood from the veins, and begins to pump. During diastole blood flows out of the arterial system through the capillaries and the arterial pressure decreases. When the arterial blood pressure is at its lowest immediately before the contracting ventricle pushes blood into the arteries this value is called the diastolic pressure. While the variation in arterial blood pressure during the cardiac cycle is smoothed out by the inherent elasticity of the major arteries, blood still exhibits

pulsatile flow through the arteries and arterioles. In this lab you will measure the pulsatile flow of blood through the finger of a student volunteer and correlate it with the ECG. In addition you will examine the effects of temperature on peripheral circulation.

Equipment Required

PC computer.

ETH-256 and National Instruments A/D Card

ECG cables and ECG pod unit

Alcohol swabs

Plethysmograph

Ice, cold and hot water, plastic bags

Equipment Setup

1 Connect the ETH-256 to the computer (described in Chapter 1).

2 The volunteer should remove all jewelry from their wrists and ankles.

3 Use an alcohol swab to clean and abrade a region of each wrist which has little or no hair.

4 Remove the plastic disk from a disposable electrode and apply the electrode to the abraded area on one wrist. Repeat for the other wrist and one ankle.

5 Attach the cable from the gray ECG pod unit to channel one on the ETH-256 unit.

6 Attach one end of each of the three electrode cables to the pod unit and snap the other ends onto the disposable electrodes, so that:

¥ The + lead is attached to the right wrist.

¥ The - lead is connected to the left leg.

¥ The ground or reference lead is connected to the left wrist.

7 Set the controls on the ETH-256 as follows

	Ch. 1: ECG pod	Ch. 2: Plethysmograph
Gain	x10	x10
High Pass	0.3 Hz	DC
Low Pass	50Hz	50Hz

8 Place the plethysmograph on the volar surface (where the fingerprints are located) of the distal segment of a middle finger; wrap the Velcro to attach the unit firmly to the end of the finger (Figure 2-7 on page 25).

9 Locate the DIN8 plug on the other end of the cable; push it into the channel two DIN8 receptacle.

10 The volunteer should sit quietly.

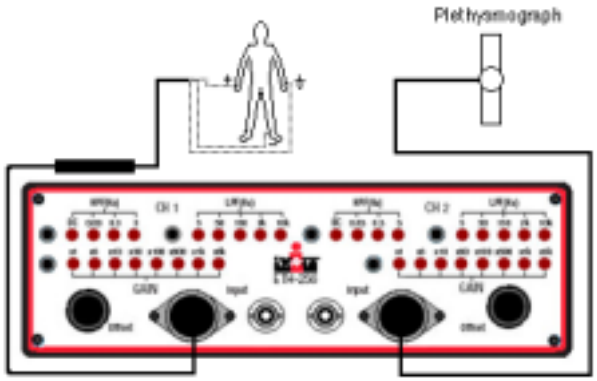

Figure 2-7: The equipment used to measure an ECG and blood flow from a volunteer.

Start the Software

1 Click the (Windows) Start menu, move the cursor to Programs and then to the iWorx folder and select LabScribe.

2 When the program opens, select Load from the Settings menu.

3 When the dialog box appears, select Human and then click OK.

4 Click on the Settings menu again and select the Heart #2 settings file.

5 After a short time, LabScribe will appear on the computer screen with the Heart #2 settings.

Exercise 1: ECG and Volume Pulse in a Resting Volunteer

Aim: To measure and correlate the ECG and volume pulse in a resting individual.

Procedure

1 Click Start and the click AutoScale in the channel one title area and see the rhythmic ECG signal.

¥ If the trace is upside down (QRS goes down) click Stop and switch the positive and negative electrodes.

¥ If a larger signal is required, the electrodes should be moved from the wrists to the skin immediately below each clavicle.

2 Click AutoScale in the channel two and then the channel three title areas and see the rhythmic finger pulse signals get bigger.

3 Type ECG and finger pulse, press Enter on the keyboard and click Stop to halt recording. Your data should look like Figure 2-8 on page 26.

4 Select Save As in the File menu, type a meaningful name and save the file in an appropriate place on the hard drive.

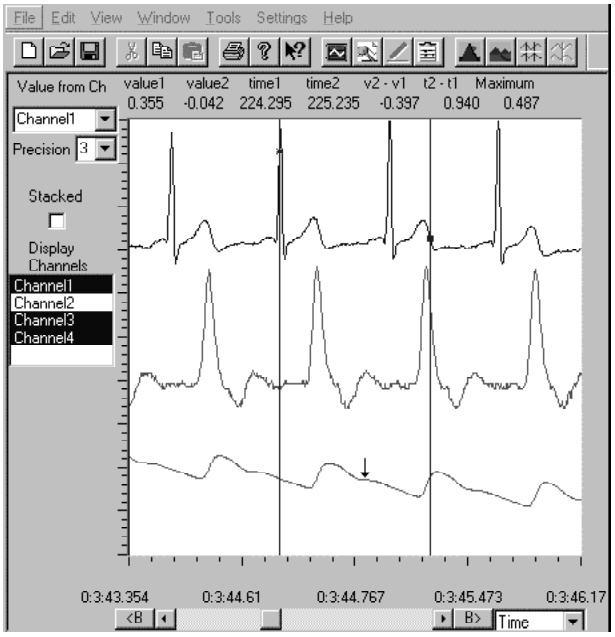

Figure 2-8: An ECG (upper trace), plethysmograph recording of blood flow (middle trace) and its integral (lower trace) shown in the Analysis window.

Data Analysis

1 Click the 2 cursor icon (Figure 2-9 on page 26), so that two blue vertical lines appear over the recording window.

2 Drag the cursors left and right so that two or three heart beat cycles are located between the two blue lines.

3 Click the Analysis icon (Figure 2-9 on page 26) to open the Analysis window.

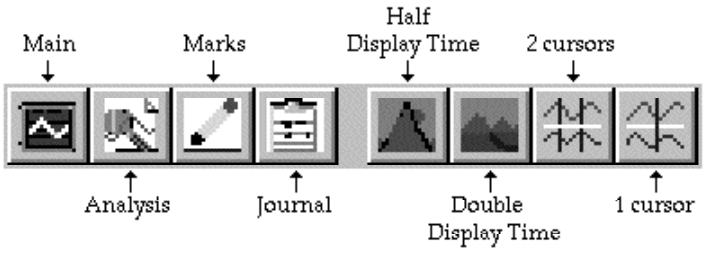

Figure 2-9: The LabScribe toolbar

4 Click to de-select channel two to display the ECG and the integrated finger pulse traces.

5 Use the mouse to click and drag one cursor to the peak of the QRS wave and the second cursor to the peak of the next finger pulse signal (Figure 2-8 on page 26).

6 Enter the time (t2-t1) difference into the Journal either by typing the values directly, or by typing a title and then transferring the title and the data set by right clicking in the Analysis window.

Questions

1 What produces the QRS wave in the ECG?

2 What does the peak of the blood flow trace represent?

3 What processes, therefore, take place between these two events?

4 What, therefore, does this time value represent?

5 Does the falling phase of the volume pulse have a small, transient plateau or upward deflection as shown in the upper trace of Figure 2-8 on page 26 (arrow)? This is called the dicrotic notch.

6 Would you expect a transient increase in blood pressure as the elastic arteries recoil after being stretched by blood entering from the ventricles?

Exercise 2: The Volume Pulse

Aim: To measure the volume pulse in other individuals.

Procedure

1 Remove the equipment from the volunteer the ECG equipment is no longer needed.

2 Strap the plethysmograph to another student, make a recording and examine the volume pulse trace.

3 Repeat for all students and type comments to label the relevant sections of data with the students names.

4 Select Save in the File menu.

Questions

1 Do all student traces have a dicrotic notch?

2 Is the size of the dicrotic notch correlated with age, smoking or fitness?

Exercise 3: The Effect of Cold on Volume Pulse

Aim: To measure the effects of cold on volume pulse and heart rate.

Procedure

1. Strap the plethysmograph to the middle finger of the volunteer s left hand.
2. Make a recording for about one minute and type cold on the keyboard.
3. Place a bag of ice and cold water on the left forearm and at the same time press Enter on the keyboard.
4. Record for about two minutes, type remove and then simultaneously remove the ice and press Enter on the keyboard.
5. Record for about two minutes and click Stop to halt recording.
6. Select Save in the File menu.

Data Analysis

1. Use the two cursors to locate the first two good adjacent peaks at the beginning of the race.
2. Use the cursors to measure:

¥ the amplitude of the two peaks; calculate the mean.

¥ the time interval between the two peaks; calculate the heart rate.

3. Repeat these measurements every 10 seconds through your trace to see the effects of cooling and subsequent recovery on peripheral circulation and heart rate. Note when ice was applied and removed in your Journal data table.

Questions

1. What is the effect of cooling on peripheral circulation?
2. What factors change peripheral circulation?
3. What is the effect of cooling on heart rate. Explain your observations.

Exercise 4: The Effect of Heat on Volume Pulse

Aim: To measure the effects of warm on volume pulse and heart rate.

Procedure

1. Move the plethysmograph to the middle finger of the right hand.
2. Repeat the above, but this time place a bag of hot water on the right forearm.

Questions

What is the effect of heat on peripheral circulation and heart rate? Explain your results.

Experiment 4: Exercise, the Electrocardiogram and Peripheral Circulation

Overview

The arterial system functions as a pressure reservoir. Blood enters via the heart and exits through the capillaries. Signals from the autonomic nervous system control the tone of smooth muscle sphincters around the arterioles. In this way, the autonomic nervous system can control the distribution of blood to the various organs in the body. The distribution of blood that flows to a particular organ is influenced by local conditions. If there are cells that require arterial blood, due to a decline in pH or oxygen levels or an increase in carbon dioxide levels, smooth muscle sphincters open to permit blood into particular capillary beds.

At rest, the distribution of blood to a particular organ may be very different from that seen during exercise. For example, the blood flow to the gut decreases during exercise while blood flow to the skeletal muscles increases dramatically. Furthermore, the amount of blood flowing around the circulatory system may be increased several times. In this laboratory you will record the electrocardiogram and the finger pulse from a (healthy) volunteer. These parameters will be recorded when the volunteer is at rest and immediately after exercise.

Warning: *This experiment involves exercise and an elevation of heart rate; this experiment should not be performed by anyone who is not healthy or has a personal or family history of cardiovascular or respiratory problems.*

Equipment Required

PC computer

ETH-256 and National Instruments A/D Card

ECG cables and ECG pod unit

Alcohol swabs

Plethysmograph

Hand dynamometer

Equipment Setup

1 Connect the ETH-256 unit to the A/D card (described in Chapter 1).

2 The volunteer should remove all jewelry from their wrists and ankles.

3 Use an alcohol swab to clean and abrade a region of each wrist which has little or no hair.

4 Remove the plastic disk from a disposable electrode and apply the electrode to the abraded area on one wrist. Repeat for the other wrist and one ankle.

5 Attach the cable from the ECG pod unit to channel one on the ETH-256 unit.

6 Attach the snap end of each of the three electrode cables to the disposable electrodes, so that:

¥ The + lead is attached to the right wrist.

¥ The - lead is connected to the left leg.

¥ The ground or reference lead is connected to the left wrist.

7 Place the plethysmograph on the volar surface (where the fingerprints are located) of the distal segment of a middle finger; wrap the Velcro to attach the unit firmly to the end of the finger (Figure 2-10 on page 30).

8 Locate the DIN 8 plug on the other end of the plethysmograph cable; push it into the pod connector on channel two.

9 Set the controls on the ETH-256 as follows:

	Ch. 1: ECG pod	Ch. 2: Plethysmograph
Gain	x10	x10
High Pass	0.3 Hz	DC
Low Pass	50Hz	50Hz

10 The volunteer should sit quietly.

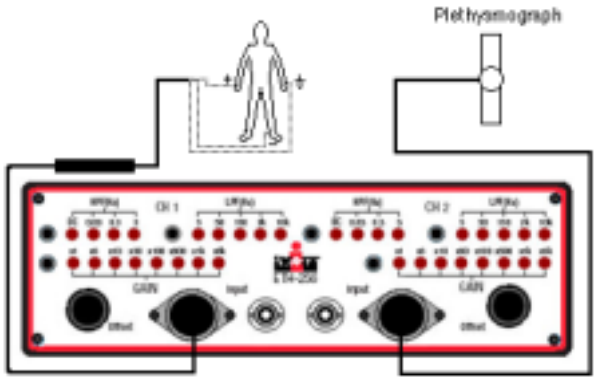

Figure 2-10: Equipment used to measure an ECG and blood flow from a volunteer.

Start the Software

1. Click the (Windows) Start menu, move the cursor to Programs and then to the iWorx folder and select LabScribe.
2. When the program opens, select Load from the Settings menu.
3. When the dialog box appears, select Human and then click OK.
4. Click on the Settings menu again and select the Heart #3 settings file.
5. After a short time, LabScribe will appear on the computer screen with the Heart #3 settings.

Exercise 1: ECG and Volume Pulse in a Resting Volunteer

Aim: To measure and correlate the ECG and volume pulse in a resting individual.

Procedure

1. Click Start and the click AutoScale in the channel one title area and see the rhythmic ECG signal.

¥ If the trace is upside down (QRS goes down) click Stop and switch the wrist electrodes.

¥ If a larger signal is required, the electrodes should be moved from the wrists to the skin immediately below each clavicle.

2. Click AutoScale in the channel two and then in the channel three title areas and see the rhythmic finger pulse and integrals signals get bigger.
3. Type ECG and finger pulse, press Enter on the keyboard and click Stop to halt recording. Your data should look like Figure 2-11 on page 32.
4. Select Save As in the File menu, type a meaningful name and save the file in an appropriate place on the hard drive.

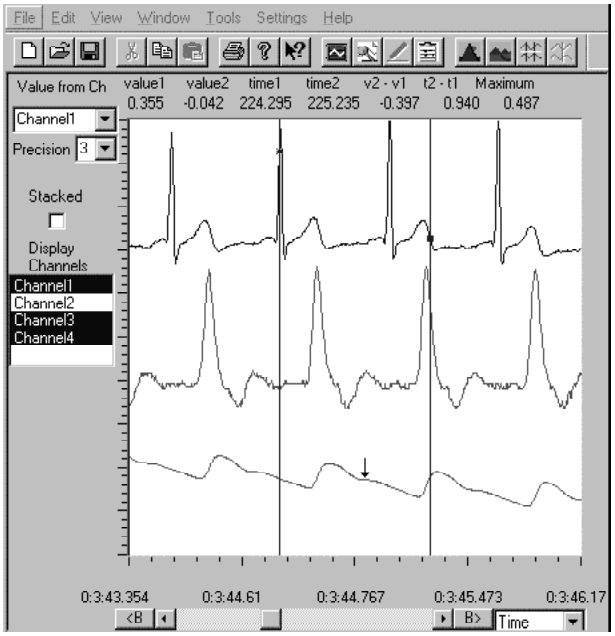

Figure 2-11: An ECG (upper trace), plethysmograph recording of blood flow (middle trace) and its integral (lower trace) shown in the Analysis window.

Exercise 2: ECG and Volume Pulse after Exercise

Aim: To measure and correlate the ECG and volume pulse immediately after exercise.

Procedure

1. Disconnect the ECG leads and the plethysmograph BNC connector from the ETH-256. Check that the ECG leads are not tangled.
2. Remember that the ECG leads are still attached to the electrodes, so the volunteer should exercise carefully (so as not to break the leads), but vigorously enough to elevate heart rate. Try walking up stairs.
3. Immediately after exercise, connect the two connectors into the ETH-256 while the volunteer sits down and relaxes.
4. Click Start, and record until the heart (and breathing) rate have returned to normal; during this time type ECG and finger pulse recovery from exercise and press the Enter key on the keyboard. Record for at least two minutes.
5. Click Stop to halt recording.
6. Select Save in the File menu.

Data Analysis

You should have traces for the resting individual and immediately after exercise. For the resting condition:

1. Click the 2 cursor icon (Figure 2-12 on page 33), so that two blue vertical lines appear over the recording window.
2. Drag the cursors left and right so that three heart beat cycles are located between the two blue lines.
3. Click the Analysis icon (Figure 2-12 on page 33) to open the Analysis window.

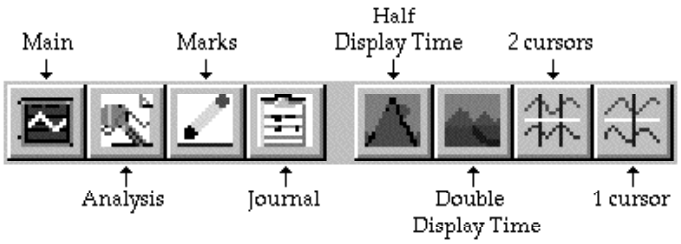

Figure 2-12: The LabScribe toolbar

4. Click to de-select channels two and three to display only the ECG.
5. Use the mouse to click and drag the two cursors to measure (Figure 2-13 on page 34) within each cardiac cycle (three measurements for each trace):

   P-R time interval

   R-T time interval

   T-P time interval

   Between cardiac cycles (two measurements for each trace):

   R-R time interval

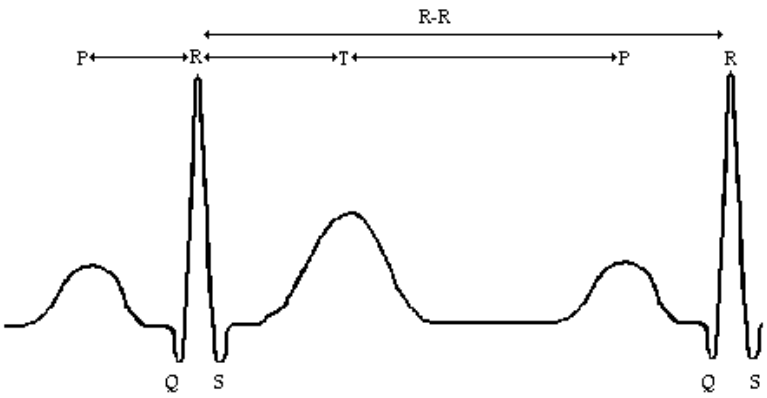

Figure 2-13: An ECG trace recorded from a volunteer with labels to indicate the time values to be measured during data analysis.

6 Enter the time (t2-t1) difference into the Journal either by typing the values directly, or by typing a title and then transferring the title and the data set by right clicking in the Analysis window.

Repeat the above measurements using the first good ECG traces immediately after, 30 seconds after and 60 seconds after exercise. Enter your labeled data into your journal.

Questions

1 Look at the three values for the P-R interval in the resting person. Are they constant? Explain any variation.

2 Look at the three values for the P-R interval immediately after exercise. Are they constant? Explain any variation.

3 Look at the three values for the P-R interval 30 and then 60 seconds after exercise. Are the values constant within each set of data? Explain any variation and trends for the three sets of data obtained at different intervals (0, 30, 60 seconds) after exercise.

4 Repeat steps 1 through 3 for the R-T, T-R and R-R intervals.

5 Look at the two values for R-R interval at rest and for the three times after exercise. Are they the same? If not, why not.

6 Calculate the differences in the mean values of the time values obtained at rest and immediately after exercise, and tabulate in your Journal.If the R-R interval is used to determine heart rate, can any of the other three intervals (P-R, R-T, or T-P) fully account for this change?

More Data Analysis

1. Look at the finger pulse trace recorded immediately after exercise.
2. Use the cursors to measure the amplitude of a signal every 10 seconds for the entire record, or until the signal has returned to a resting level for 30 seconds (i.e. three or four measurements that are reasonably constant).

Questions

1. What is the effect of exercise on the rate of blood flow through the fingers?
2. Is it possible that blood flow may be effected more if the exercise is directed at the arm rather than a generalized change in circulation?

Exercise 3: Finger Pulse after Hand Exercise

Aim: To measure and correlate the ECG and volume pulse immediately after exercise.

Procedure

1. Disconnect the ECG leads from the volunteer.
2. Grasp the dynamometer in the palm of the left hand (the hand to which the plethysmograph is attached).

Note: *The dynamometer is not plugged in to the ETH-256 at this time.*

3. Rhythmically squeeze the dynamometer bulb for a few minutes or until the forearm muscles fatigue.
4. Click Start and stop exercising record for three minutes or until the amplitude of the finger pulse signal has attained a reasonably constant level for one minute; during this time type Finger pulse recovery from arm exercise and press the Enter key on the keyboard.
5. Click Stop to halt recording.
6. Select Save in the File menu.

Data Analysis

1. Look at the finger pulse trace recorded immediately after exercise.
2. Use the cursors to measure the amplitude of a signal every 10 seconds for the entire record, or until the signal has returned to a resting level for 30 seconds (i.e. three or four measurements that are reasonably constant) .
3. Enter your data into the Journal.

Questions

1. What is the effect of hand exercise on the rate of blood flow through the fingers?
2. Compare the data from the first session of exercise. Are they the same or different? Explain your data.

Experiment 5: Blood Pressure, Peripheral Circulation and Body Position

Overview

The ventricles contract to push blood into the arterial system and then relax to fill with blood before pumping once more. This intermittent ejection of blood into the arteries is balanced by a constant loss of blood from the arterial system through the capillaries. When the heart pushes blood into the arteries there is a sudden increase in pressure, which slowly declines until the heart contracts again. Thus, the pressure in the arteries varies during the cardiac cycle, being at its highest level immediately after the ventricle contracts (systolic pressure) and at its lowest level immediately prior to the pumping of blood into the arteries (diastolic pressure). These two values are traditionally measured by a trained nurse using a stethoscope and a blood pressure cuff. The cuff is placed on the upper left arm and inflated to stop arterial blood flow to the arm the cuff creates a high pressure which causes the arteries to collapse. The pressure in the cuff is released and when the systolic pressure in the arteries is greater than in the cuff, blood flows momentarily to the arm through the partially collapsed artery this is heard through the stethoscope and the systolic pressure is noted from the pressure gauge on the cuff. When cuff pressure declines to the diastolic pressure the sound heard through the stethoscope changes and this value is noted as the diastolic pressure.

Measuring blood pressure using a blood pressure cuff and a stethoscope takes a great deal of practice. While this technique may not be easily applied in this laboratory, you will measure blood pressure using a blood pressure cuff and a plethysmograph unit. In addition to measuring the blood pressure from all willing participants, the effects of cuff location, body position and arm position will be examined.

Warning: *As explained above, this procedure involves stopping blood flow to the arm. This is potentially dangerous. Please take the following precautions:*

1. Know what you are doing ahead of time.
2. Do not leave the cuff inflated for any prolonged period of time (>30 seconds).
3. The volunteer should flex and extend their fingers between experiments to maintain blood flow.
4. This experiment should be performed by healthy individuals who do not have a personal or family history of cardiovascular or respiratory problems. If possible, use more than one volunteer during the course of the lab session.

Equipment Required

PC computer

ETH-256 and National Instruments A/D Card

Plethysmograph

Blood pressure cuff

Equipment Setup

1. Connect the ETH-256 unit to the A/D card (described in Chapter 1).
2. Untangle to plethysmograph cable.
3. Place the plethysmograph on the volar surface (where the fingerprints are located) of the distal segment of a middle finger; wrap the Velcro to attach the unit firmly to the end of the finger
4. Push the DIN plug on the other end of the cable into the socket labeled channel one.
5. Place the blood pressure cuff around the upper portion of the left arm, between the elbow and the shoulder.
6. Set the controls on the ETH 256 as follows:

	Ch. 1: Pulse sensor	Ch. 2: No Device
Gain	x10	x1
High Pass	DC	DC
Low Pass	50Hz	50Hz

7. The volunteer should sit quietly.

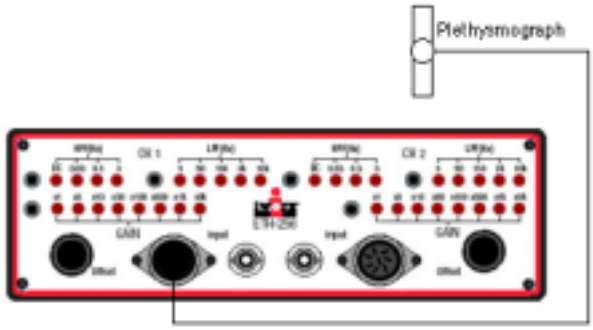

Figure 2-14: The equipment used to measure blood flow from a volunteer.

Start the Software

1. Click the (Windows) Start menu, move the cursor to Programs and then to the iWorx folder and select LabScribe.
2. When the program opens, select Load from the Settings menu.
3. When the dialog box appears, select Human and then click OK.
4. Click on the Settings menu again and select the Heart #4 settings file.
5. After a short time, LabScribe will appear on the computer screen with the Heart #4 settings.

Exercise 1: Procedure for Measuring Blood Pressure

Aim: To measure blood pressure.

Procedure

1. Ask the volunteer to sit down and relax, with both hands in their lap.
2. Click Start and record the finger pulse.
3. Click AutoScale in the channel one title area and see the rhythmic signal get bigger. During this initial recording type a brief description of the experiment that is about to be performed and press Enter on the keyboard.
4. Inflate the cuff until the pressure is just above 200 mmHg notice that the finger pulse disappears (Figure 2-15 on page 39).

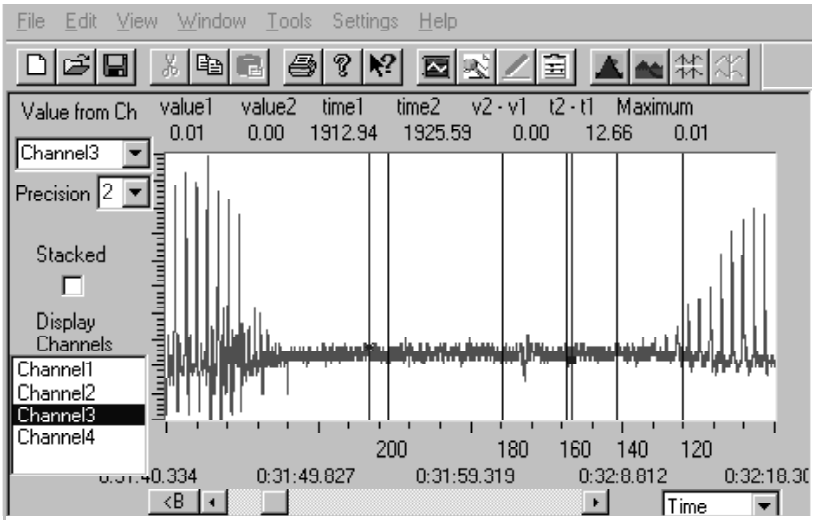

Figure 2-15: A finger pulse recorded during blood pressure measurements. In this experiment a few pulses were recorded (left) before inflating the cuff around the left upper arm. As the pressure in the cuff exceeded that in the artery the volume pulse signal disappeared, indicating that blood circulation had ceased. As the cuff pressure was released (marked in 20mmHg increments from 200) the signal appeared around 120mmHg and level out around 80mmHg.

5 Slowly release the cuff pressure; when the pressure reaches 200 press the Enter key on the keyboard do not type, use the comments marker as an indicator of pressure. Press the Enter key every time the pressure drops by 20mmHg.

6 When the cuff reaches 40 click Stop and remove the cuff. The volunteer should flex and extend their fingers to encourage blood circulation

7 Select Save As in the File menu, type a meaningful name and save the file in an appropriate place on the hard drive.

Data Analysis - Measuring Blood Pressure

Systolic Pressure

1 Click the 2 cursor icon (Figure 2-16 on page 40), so that two blue vertical lines appear over the recording window.

2 Drag the cursors left and right to place them on either side of a pair marks between which the finger pulse signal first appears (between 140 and 120 in Figure 2-17 on page 40).

3 Click the Analysis icon (Figure 2-16 on page 40) to open the Analysis window.

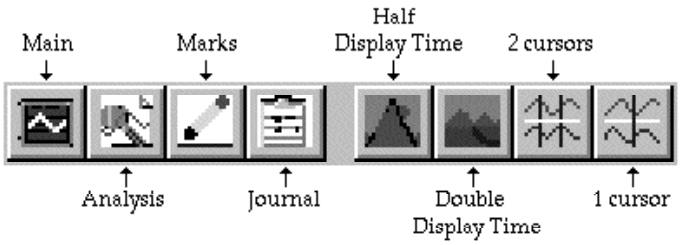

Figure 2-16: The LabScribe toolbar

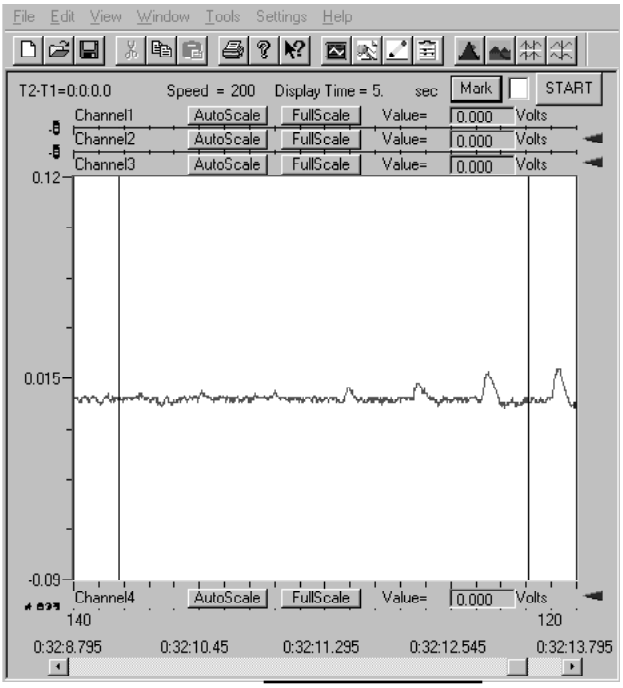

Figure 2-17: The finger pulse trace showing the recording taken as cuff pressure declined from 140 (left) to 120 (right) mmHg.

4 Place one cursor on the peak of the smallest signal (Figure 2-17 on page 40) and the second cursor on the Mark entered prior to the peak. Measure the time interval (t2-t1) and call this time value #1. Repeat with the second cursor on the comment entered after the peak call this time value #2.

5 Calculate:

$$\frac{\text{value \#2 x 20}}{\text{value \#1 + value \#2}}$$

6 Add this number to the lowest value in the bracket (100 in the above example) to give you the systolic pressure.

Diastolic Pressure

Look at your recording and notice that the amplitude of the finger pulse increases until it reaches (and stays at) its largest amplitude. Repeat the above for the largest peak to give you the diastolic pressure.

Exercise 2: Repeat the Measurement

Aim: To determine the accuracy of the blood pressure measurement.

Procedure

Repeat the procedures outlined in exercise #1 using the same volunteer.

Questions

1. Are the values for blood pressure (systolic and diastolic) identical? Can you explain any variation?
2. Since you are looking for changes in the volume pulse, would slowing the rate of pressure released from the cuff make your readings more accurate?

Note: *If you decide to slow the release of the cuff pressure, remember that restricting circulation for a prolonged period can be dangerous.*

Exercise 3: Measurements from the Right Arm

Aim: Measure blood pressure from the right arm.

Procedure

¥ a control experiment:

1. With the plethysmograph still on the left hand, place the cuff around the upper portion of the right arm.
2. Inflate the cuff does the finger pulse signal disappear? Deflate the cuff. Why does the finger signal remain after inflation?

¥ the right arm:

1. Place the plethysmograph on the distal segment of the middle finger of the right hand and wrap the Velcro to attach the unit firmly to the end of the finger.

2 Measure the blood pressure as described above, making two separate measurements.

Questions

Are the values the same as those obtained for the left arm? Explain any differences

Exercise 4: Measurements with the Cuff on the Forearm

Aim: To examine whether the blood pressure declines with distance from the heart.

Procedure

1 Move the cuff from the upper right arm to the lower right arm.

2 Measure the blood pressure as described above.

Questions

Are the values the same as those obtained with the cuff on the forearm? Explain your data.

Exercise 5: Arm Position

Aim: To examine the effects of gravity on blood pressure and peripheral circulation.

Procedure

1 Move the cuff to the upper left arm (this may be a good time to switch volunteers).

2 Measure the amplitude of the finger pulse and blood pressure with both hands in lap.

3 Have the volunteer place their right hand on their head and repeat step 2.

4 Have the volunteer place their left hand on their head and repeat step 2.

Questions

What is the effect of raising each hand on finger pulse and blood pressure in the left arm? Explain your results.

Exercise 6: Measurements from the Leg

Aim: Measure blood pressure and peripheral circulation from the leg.

Procedure

1. The volunteer should sit and remove the left shoe and sock.
2. Place the plethysmograph on the distal segment of the big toe and wrap the Velcro to attach the unit firmly to the end of the toe.
3. Wrap the cuff around the calf of the left leg.
4. Inflate the cuff and measure the blood pressure as described above, making two separate measurements.

Questions

1. Are the values the same as those obtained for the arms? Explain any differences.
2. What happens to finger pulse and blood pressure when:

¥ the volunteer lies down on the bench?

¥ the prone volunteer lifts their left leg perpendicular to the bench (support the leg with a chair)?

¥ the volunteer stands?

¥ after the volunteer has been standing for three minutes?

Experiment 6: Blood Pressure, Peripheral Circulation and Imposed Conditions

Overview

The ventricles contract to push blood into the arterial system and then relax to fill with blood before pumping once more. This intermittent ejection of blood into the arteries is balanced by a constant loss of blood from the arterial system through the capillaries. When the heart pushes blood into the arteries there is a sudden increase in pressure (called the systolic pressure), which slowly declines until the heart contracts again (the lowest arterial pressure is called the diastolic pressure). In the previous lab these two pressure values were measured from willing volunteers in a study of the effects of cuff location and body position on blood pressure.

In this lab there will be a long-term experiment and a series of short-term experiments. Volunteers engaged in the long-term experiment will examine the effects of food additive on heart rate, blood pressure and peripheral circulation. Other volunteers will be engaged in a number of short-term experiments to see the effects of apnea, exercise and temperature on blood pressure and peripheral circulation.

Warning: *As explained previously, this procedure involves stopping blood flow to the arm. This is potentially dangerous. Please take the following precautions:*

1. Know what you are doing ahead of time.
2. Do not leave the cuff inflated for any prolonged period of time (>30 seconds).
3. The volunteer should flex and extend their fingers between experiments to maintain blood flow.
4. This experiment should be performed by healthy individuals who do not have a personal or family history of cardiovascular or respiratory problems. If possible, use more than one volunteer during the course of the lab session.

Equipment Required

PC computer

ETH-256 and National Instruments A/D card

Plethysmograph

Blood pressure cuff

Plastic bag, ice, and cold and hot water

Equipment Setup

1. Connect the ETH-256 unit to the A/D card (described in Chapter 1).
2. Untangle the plethysmograph cable.
3. Place the plethysmograph on the volar surface (where the fingerprints are located) of the distal segment of a middle finger; wrap the Velcro to attach the unit firmly to the end of the finger.
4. Push the DIN 8 plug on the other end of the cable into the socket labeled channel one.
5. Place the blood pressure cuff around the upper portion of the left arm, between the elbow and the shoulder.
6. Set the controls on the ETH-256 as follows:

	Ch. 1: Plethysmograph	Ch. 2: No Device
Gain	x10	x1
High Pass	DC	DC
Low Pass	50Hz	50Hz

7. The volunteer should sit quietly.

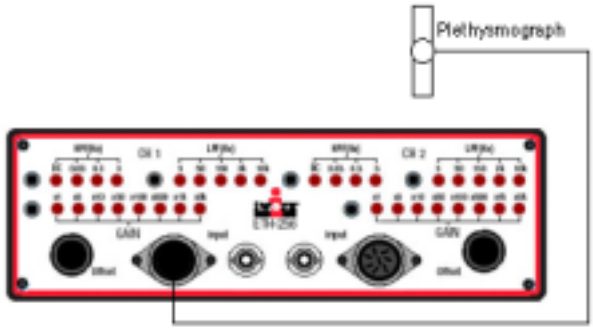

Figure 2-18: The equipment used to measure blood flow from a volunteer.

Start the Software

1. Click the (Windows) Start menu, move the cursor to Programs and then to the iWorx folder and select LabScribe.
2. When the program opens select Load from the Settings menu.
3. When the dialog box appears select Human and then click OK.
4. Click on the Settings menu again and select the Heart #5 settings file.
5. After a short time, LabScribe will appear on the computer screen with the Heart #5 settings.

Exercise 1: Procedure for Measuring Blood Pressure

Aim: To measure blood pressure.

Procedure

1. Ask the volunteer to sit down and relax, with both hands in their lap.
2. Click Start and record the finger pulse.
3. Click AutoScale in the channel one title area and see the rhythmic signal get bigger. During this initial recording type a brief description of the experiment that is about to be performed and press Enter on the keyboard.
4. Inflate the cuff until the pressure is just above 200mmHg notice that the finger pulse disappears (Figure 2-19 on page 46).

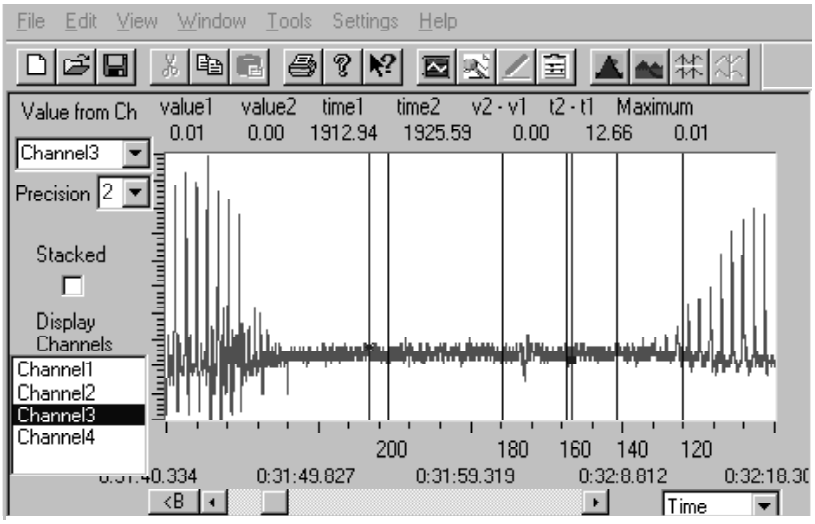

Figure 2-19: A finger pulse recorded during blood pressure measurements. In this experiment a few pulses were recorded (left) before inflating the cuff around the left upper arm. As the pressure in the cuff exceeded that in the artery the volume pulse signal disappeared, indicating that blood circulation had ceased. As the cuff pressure was released (marked in 20mmHg increments from 200) the signal appeared around 120mmHg and level out around 80mmHg.

5 Slowly release the cuff pressure; when the pressure reaches 200 press the Enter key on the keyboard do not type, use the comments marker as an indicator of pressure. Press the Enter key every time the pressure drops by 20mmHg.

6 When the cuff reaches 40 click Stop and remove the cuff.The volunteer should flex and extend their fingers to encourage blood circulation

7 Select Save As in the File menu, type a meaningful name and save the file in an appropriate place on the hard drive.

Data Analysis - Measure Blood Pressure

Systolic Pressure

1 Click the 2 cursor icon (Figure 2-20 on page 47), so that two blue vertical lines appear over the recording window.

2 Drag the cursors left and right to place them on either side of a pair marks between which the finger pulse signal first appears.

3 Click the Analysis icon (Figure 2-20 on page 47) to open the Analysis window.

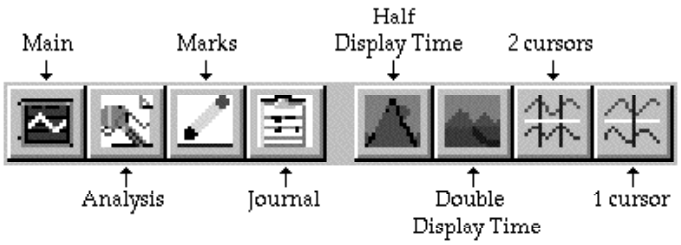

Figure 2-20: The LabScribe toolbar

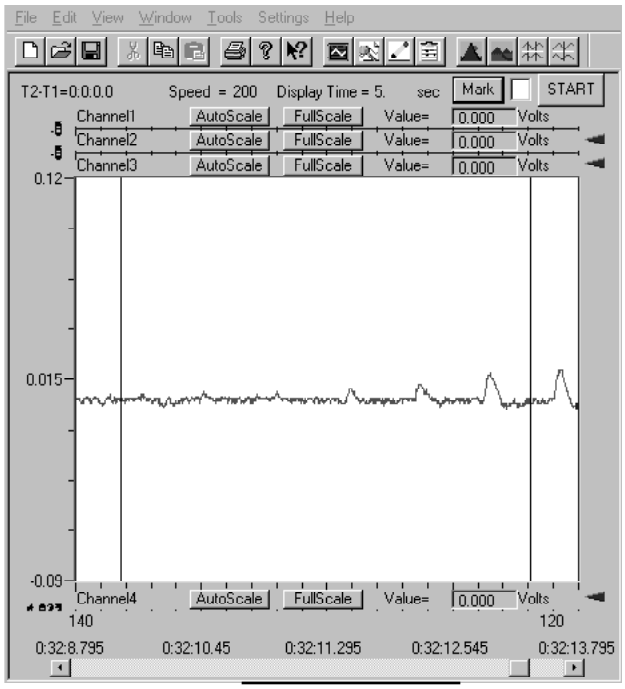

Figure 2-21: The finger pulse trace showing the recording taken as cuff pressure declined from 140 (left) to 120 (right) mmHg.

4 Place one cursor on the peak of the smallest signal (Figure 2-21 on page 47) and the second cursor on the Mark entered prior to the peak. Measure the time interval (t2-t1) and call this time value #1. Repeat with the second cursor on the comment entered after the peak (Figure 2-21 on page 47) call this time value #2.

5 Calculate:

$$\frac{\text{value \#2} \times 20}{\text{value \#1} + \text{value \#2}}$$

6 Add this number to the lowest value in the bracket (100 in the above example) to give you the systolic pressure.

Diastolic Pressure

Look at your recording and notice that the amplitude of the finger pulse increases until it reaches (and stays at) its largest amplitude. Repeat the above for the largest peak to give you the diastolic pressure.

Lab Procedure

Two types of experiments will be performed in this lab, and student volunteers should participate in only one type of experiment:

Long-term experiment - in which measurements are taken every 20 minutes throughout the lab.

Short-term experiments - in which measurements are taken during a manipulation conducted in the periods between the long-term experiment.

Exercise 2: Effects of Food Additives (long-term)

The effect of food additives will be examined as a class project. If there are 10 groups, one individual from each group should participate in the long-term project. One suggestion includes having each willing individual drink 12 ounces of one of the following:

¥ regular soda

¥ sugar-free soda

¥ decaffeinated, regular soda

¥ decaffeinated, sugar-free soda

¥ Water (control)

Other possible studies could include the effects of smoking a cigarette (if there are regular smokers in the class), aspirin and other non-prescription pain relievers, monosodium glutamate, and sports drinks with different levels of sugar and salt.

Procedure

1 Ask the volunteer to sit down and relax, with both hands in their lap.

2 With the cuff around the left upper arm and the plethysmograph on the left middle finger:

¥ Measure the volume pulse for 30 seconds.

¥ Inflate the cuff and slowly deflate to measure blood pressure.

3 Have the volunteer drink their designated soda.

4 Repeat steps #1 and #2 every 20 minutes (enter appropriate comments, including the time after the drink).

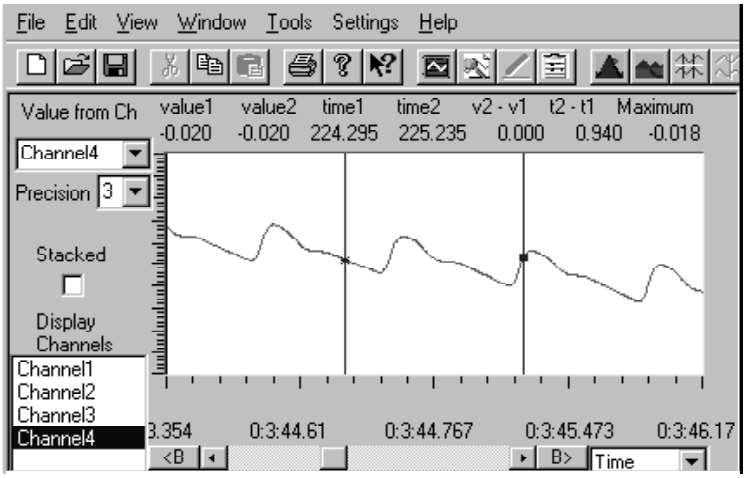

Figure 2-22: The integral of the plethysmograph signal in the Analysis window.

Data Analysis

1. Measure the blood pressure, the amplitude of the volume pulse (place the cursors prior to and at the peak of the pulse signal) and the time interval between successive pulses (Figure 2-22 on page 49).
2. Use a line graph to show the effects over time.

Questions

1. Compare the data sets to see the effects of the different additives on blood pressure, peripheral circulation and heart rate.
2. Explain your results

The Short-Term Experiments

These should be performed by volunteers who are not engaged in the long-term project the long-term individuals can be responsible for data accumulation at this stage.

Exercise 3: Effects of Exercise

Aim: To examine the effects of exercise on blood pressure.

Procedure

1. Loosely attach the blood pressure cuff to the volunteer s left upper arm, and firmly wrap the plethysmograph s Velcro strap around the distal segment of the left middle finger.
2. Remove the plethysmograph s connector from the ETH-256 unit and ask the volunteer to hold it in their left hand.

3. Ask the volunteer to exercise carefully, with minimal class disruption but rigorously enough to elevate heart rate. Try walking up and down stairs.
4. Immediately after exercise, reattach the connector to channel one.
5. Click Start, inflate the cuff and measure the blood pressure; after deflation type recovery from exercise and press the Enter key on the keyboard.
6. Click Stop to halt recording.
7. Select Save from the File menu.

Data Analysis

Measure blood pressure after exercise.

Questions

Compare the blood pressure before and after exercise. Does exercise change blood pressure?

Exercise 4: Apnea (holding breath)

Aim: To examine the effects of apnea on blood pressure and peripheral circulation.

Procedure

1. If a new volunteer is used, first measure their resting blood pressure.
2. As a preliminary study, simply record volume pulse and have the volunteer take in a deep breath, hold it for as long as possible, and then breathe normally (type appropriate comments during the experiment).

Questions

1. What is the effect of periods of apnea on heart rate and the amplitude of the volume pulse?
2. Are there any changes when breathing is initiated once more?
3. Explain your results. Do you think apnea has an effect on blood pressure?

Procedure

Repeat the above procedure and measure blood pressure when the volunteer in holding their breath.

Questions

1. What is the effect of apnea on blood pressure?
2. Explain your results.

Exercise 5: Cooling the Forearm

Aim: To examine the effects of cooling the forearm on blood pressure, heart rate and peripheral circulation.

Procedure

1. Place the plethysmograph on the right middle finger.
2. Record volume pulse for 60 seconds.
3. Apply a bag of ice water on the volunteer s right forearm.
4. Remove after two minutes and record during recovery until the volume pulse trace is reasonably consistent in amplitude for about 30 seconds.

Data Analysis

1. Select the first two good adjacent peaks at the beginning of the volume. pulse trace.
2. Use the two cursors to measure:

¥ the amplitude of the two peaks; calculate the mean.

¥ the time interval between the two peaks; calculate the heart rate.

3. Repeat these measurements every 15 seconds through your trace to see the effects of cooling and subsequent recovery on peripheral circulation and heart rate. Note when ice was applied and removed.
4. Graph your results with respect to time, indicating the time when ice was applied and removed.

Questions

1. What is the effect of cooling on peripheral circulation and heart rate? Explain your data.
2. Would you expect blood pressure to change during this process?

Procedure

1. Place the plethysmograph on the left middle finger and the cuff on the left upper arm.
2. Repeat the above procedure, but measure blood pressure quickly after the ice bag has been applied to the left forearm.

Questions

What is the effect of cooling on blood pressure? Explain your data.

Exercise 6: Warming the Forearm

Aim: To examine the effects of warming the forearm on blood pressure, heart rate and peripheral circulation.

Procedure

Repeat Exercise #5, except use a bag of warm water and another volunteer.

Chapter 3: Neuromuscular Physiology

Overview

The bones of the skeleton provide support for the body and articulate at joints, which act as pivots points. The associated skeletal (or striated) muscles have bundles of collagen, called tendons, connecting them to the bones. These points of muscle attachment are usually close to the joint, so that a small contraction produces a large movement. Two or more muscles usually work antagonistically so that a contraction of one stretches the other.

Striated muscle is composed of multi nucleate cells called fibers. Each fiber consists of numerous thread-like myofibrils which have a banded appearance created by a series of repeated units, called sarcomeres, joined end-to-end. The ends of the sarcomere are marked by Z lines, the I band lies on either side of the Z line, and the A band is found in the center of the sarcomere (Figure 3-1 on page 53). The I band is composed of thin filaments which project from the Z line while the A band has thick filaments and overlapping thin filaments (Figure 3-1 on page 53).

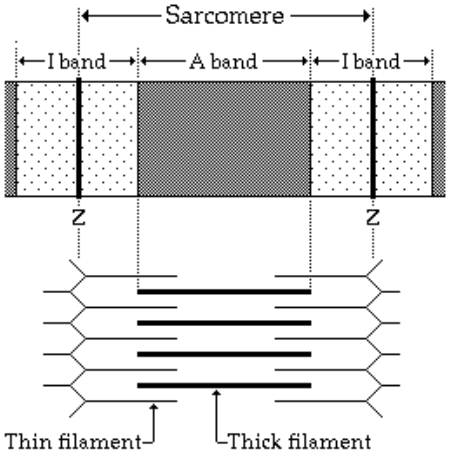

Figure 3-1: A diagram of a sarcomere showing the Z lines, I bands and A band (upper) and the associated protein filaments (lower).

Thick filaments are made up of the protein myosin. A myosin molecule is composed of two polypeptide chains, each with a globular head and a long tail (Figure 3-2 on page 54). Myosin molecules are laid down so that the tails form the body of the thick filament, and the heads hang off. Thin filaments are composed primarily of actin (Figure 3-2 on page 54), which form a double helix and have binding sites for myosin. According to the sliding filament theory the thick and thin filaments slide across one another to shorten the sarcomere. This is achieved by a reaction between the myosin heads and the actin molecules to form cross bridges. The rapid making and breaking of these bonds together with the conformational (shape) changes in the myosin head, produces the tension required to create a contraction.

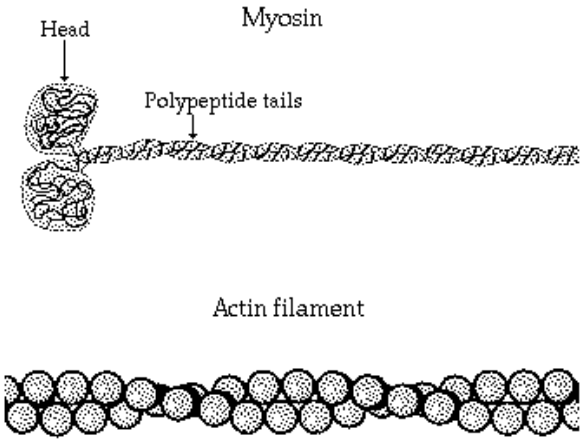

Figure 3-2: Diagrams of the myosin molecule and an actin filament each sphere represents a molecule of globular actin in the helical chain.

In skeletal neuromuscular systems, an action potential in a motor axon produces an action potential in the muscle fibers it innervates. This activity increases the intracellular level of calcium, which binds to troponin, a globular regulatory protein on the thin filaments. The resultant change in the shape of troponin effects the location of tropomyosin, a second associated regulatory protein on the thin filaments, and exposes the myosin binding sites on the actin molecules. Cross bridges between the myosin and actin are repeatedly made and broken to shorten the sarcomeres. Thus, the muscle contracts during the transient period when the level of calcium inside the muscle is elevated.

Experiment 7: Electromyograms (EMGs)

Overview

A skeletal muscle fiber is innervated by a branch of a motor neuron. Under normal circumstances a neuronal action potential activates all of the muscles innervated by the motor neuron. This activation process involves an action potential and a contraction of the muscle s fibers. During a contraction, therefore, there is synchronous activity in a number of fibers in the same muscle. The electrical signal recorded from a contracting muscle is called an electromyogram or EMG. As in the electrocardiogram (ECG), this activity can be detected by electrodes placed on the skin; in fact, such electrical activity was recorded during finger movements in Exercise #1 of Experiment 2. A muscle contraction is produced by one or more action potentials in many fibers. The EMG, therefore, is not a series of predictable waves seen during the ECG, but a burst of seemingly spike-like signals. On-line integration helps reading this complex signal, since the wave gives an indication of the intensity of muscle activity during a contraction.

In this lab you will record EMGs from arm muscles and examine recruitment, tetanus, and temporal motor activity to antagonistic muscles.

Equipment Required

PC computer

ETH-256 and National Instruments A/D card

EMG cables and black pod unit

Alcohol swabs

Equipment Setup

1. Connect the ETH-256 unit to the A/D card (described in Chapter 1).
2. The volunteer should remove all jewelry from their wrists and ankles.
3. Use an alcohol swab to clean and abrade the three regions for electrode attachment on the right forearm, as shown in Figure 3-3 on page 56.
4. Remove the plastic disk from a disposable electrode and apply the electrode to one abraded area. Repeat for the other two areas.
5. Attach the cable from the black pod unit to channel one on the ETH-256 unit.

6 Set the controls on the ETH-256 as follows:

	Ch. 1: EMG	Ch. 2: No Device
Gain	x10	x1
High Pass	3 Hz	DC
Low Pass	5KHz	50Hz

7 Attach the three electrode cables to the pod unit and snap the other ends onto the disposable electrodes, as shown in Figure 3-3 on page 56.

8 The volunteer should hold a small object (like keys or a pen knife) in their right hand.

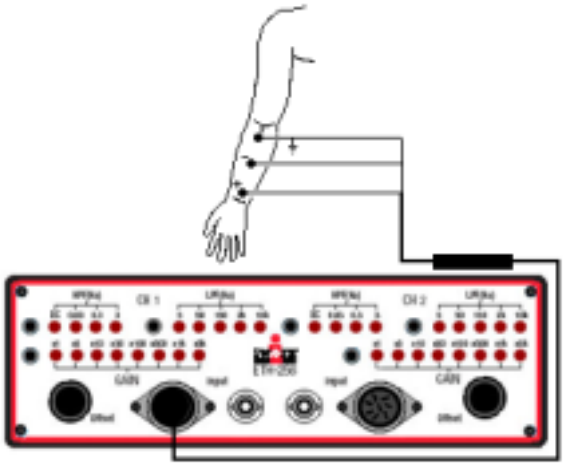

Figure 3-3: The equipment used to monitor EMGs and resulting finger movements from a volunteer.

Start the Software

1 Click the (Windows) Start menu, move the cursor to Programs and then to the iWorx folder and select LabScribe.

2 When the program opens, select Load from the Settings menu.

3 When the dialog box appears, select Human and then click OK.

4 Click on the Settings menu again and select the Muscle #1 settings file.

5 After a short time, LabScribe will appear on the computer screen with the Muscle #1 settings.

Exercise 1: Recruitment and the EMG

Aim: To examine the EMG when more fibers are recruited into a single twitch.

Procedure

1. Click Start and the click AutoScale in the channel one title area then AutoScale channel two.
2. Ask the volunteer to squeeze the object in their hand using a single, brief contraction (twitch) of the fingers. Start with a gentle contraction and gradually increase the intensity of the single twitch contractions until a maximum level is reached; press Enter on the keyboard at each contraction.
3. Type EMG and increasing twitches, press Enter on the keyboard and click Stop to halt recording.
4. Select Save As in the File menu, type a meaningful name and save the file in an appropriate place on the hard drive.

Data Analysis

1. Right click on the channel two display area and select Integrate.
2. Scroll the first twitch recording to the center of the screen.
3. Click the 2 cursor icon (Figure 3-4 on page 57), so that two blue vertical lines appear over the recording window and are located on either side of the first response.
4. Click the Analysis icon (Figure 3-4 on page 57) to open the Analysis window.

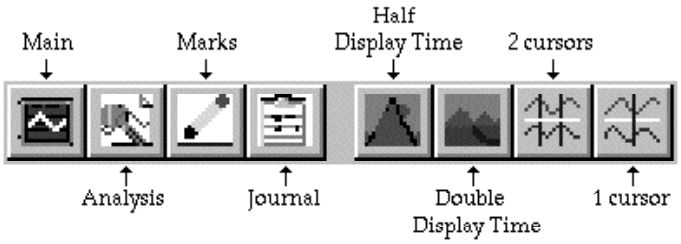

Figure 3-4: LabScribe toolbar

5. Use the mouse to click and drag one cursor to the baseline, prior to the first response, and the second cursor on the peak of the response on channel two.
6. Click in the top left margin to select data values from channel two and enter the voltage (v2-v1) difference into the Journal either by typing the values directly, or by right clicking in the Analysis window and selecting Add Data to Journal.
7. Repeat for all responses.

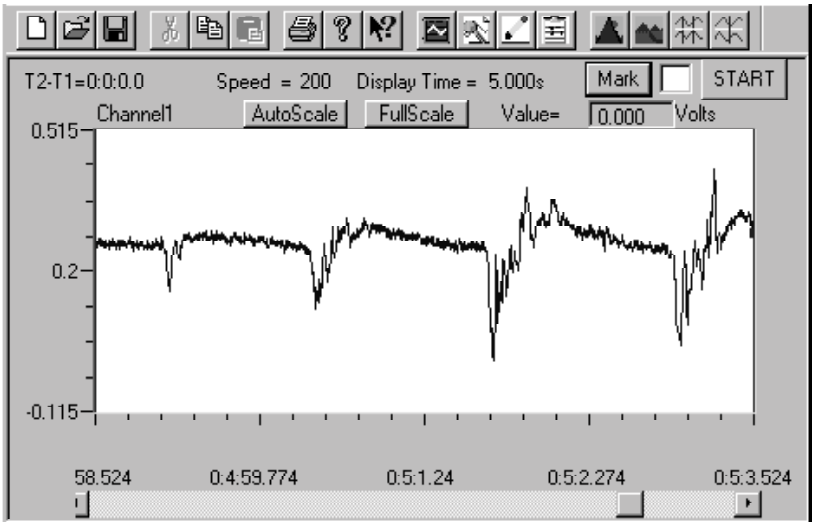

Figure 3-5: The EMG recording during three increasing finger movements.

Questions

1. Is there a correlation between the amplitude of the integrated EMG signal and the amount of contraction?
2. Look at your data. Is the duration (length) of each integrated signal about the same for each contraction? If not, this would indicate more than just a single muscle twitch i.e. some muscle fibers were stimulated for more than just a single action potential in the motor neurons.
3. Are all of the EMG responses approximately the same duration?
4. How do you explain the increase in the amplitude of the integrated EMG signal with an increase in contraction?

Hint: *If a contraction involves a single twitch of the contracting muscle fibers, how can contraction be increased without making muscle fibers more than once?*

Exercise 2: Maximum Finger Contraction

Aim: To measure the EMG when the fingers are squeezed hard.

Procedure

1. Click Start and type hard squeeze.
2. Ask the volunteer to squeeze the object in their hand as hard as possible to produce maximum tension, press Enter on the keyboard, and then relax.

3 Click Stop to halt recording.

4 Select Save in the File menu.

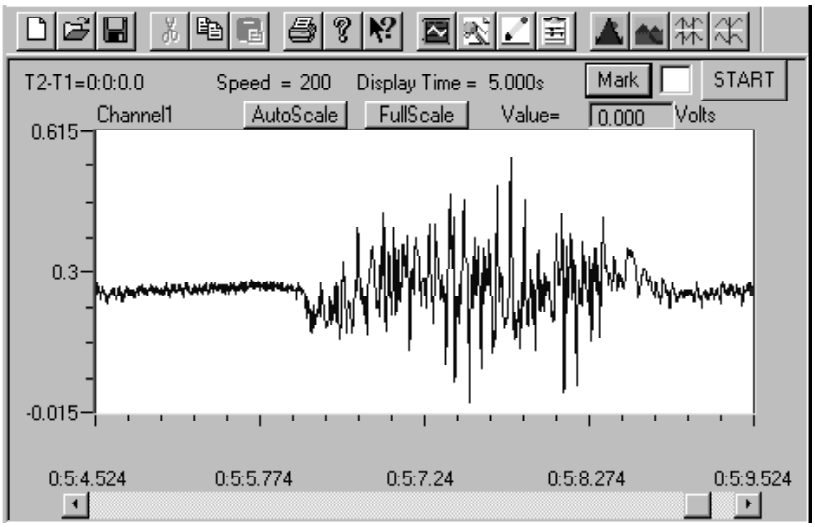

Figure 3-6: An EMG recording during a maximum contraction.

Data Analysis

Your EMG data may look like Figure 3-6 on page 59.

1 Click the 2 cursor icon (Figure 3-4 on page 57), so that two blue vertical lines appear over the recording window and are located on either side of the maximum response.

2 Click the Analysis icon (Figure 3-4 on page 57) to open the Analysis window.

3 Use the mouse to click and drag:

¥ one cursor to the baseline, prior to the first response, and the second cursor on the peak of the response on channel one read off the response amplitude (v2-v1).

¥ one cursor to the beginning of the response and the other to the end of the response on channel one read off the duration (t2-t1) of the contraction.

For all data enter the data values into the Journal either by typing them directly, or by typing a title and then transferring the title and the data set by right clicking in the Analysis window.

4 Repeat the above measurements for the last response in the previous exercise i.e. the largest single twitch.

Questions

1. Using the EMG integral data, compare the amplitude of the maximum squeeze with the maximum single twitch contraction which is larger?
2. If all fibers were contracting in both instances (maximum squeeze and single twitches) explain why the maximum squeeze produced a larger contraction.
3. Compare the duration of this maximum squeeze contraction with the maximum contraction produced by a single twitch which is longer?
4. Does your answer to question #2 fit with your answer to question #3?

Hint: *During the second exercise do you think each motor axon fired only once to produce the maximum squeeze?*

Exercise 3: Tetanus and Movement

Aim: To examine the relationship between tetanus and movement.

Procedure

Move the recording electrodes to the biceps as follows:

1. Remove the recording electrodes from the forearm and place them on the biceps as shown in Figure 3-7 on page 60.

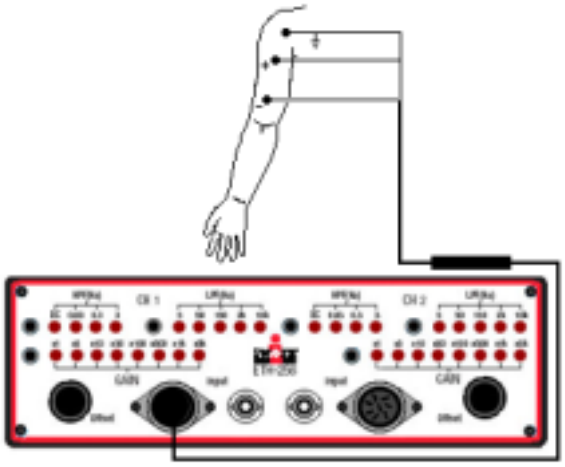

Figure 3-7: The equipment used to monitor EMGs from the biceps muscle of a volunteer.

2. Ask the volunteer to sit on a chair and support their right elbow with their left hand. Ask the volunteer to make a fist with their right hand and place the knuckles under the bench top with their palm uppermost.
3. Click Start and type tetanus.

4 Ask the volunteer to bend their right arm against the weight of the bench top, press Enter on the keyboard.

5 After 15 seconds of hard contraction ask the volunteer to stop, extend their arm and relax (the left hand should still support the right elbow). Does the right arm bend when the biceps is relaxed? Is there any myogram activity in the biceps muscle when the arm bends?

6 Click Stop to halt recording.

7 Select Save in the File menu.

Questions

1 During the contraction did the angle between the upper arm and lower arm change significantly?

2 When the volunteer relaxed after the contraction, were EMGs recorded?

3 During relaxation did the angle between the upper arm and lower arm change significantly?

4 How can you explain a movement in the absence of significant EMG activity?

Hint: *Does the level of intracellular calcium return to normal immediately after a contraction?*

Exercise 4: Integration of Motor Activity

Aim: To study activity in antagonistic muscles during normal movement.

Procedure

1 Ask the volunteer to sit on a chair and support their right elbow with their left hand.

2 Click Start and type no weight - biceps and press Enter on the keyboard.

3 Ask the volunteer to bend and extend their arm slowly type bend and press Enter every time they bend their arm. Does the right arm bend or extend when the biceps is relaxed? Is there any myogram activity in the biceps muscle when the arm extends?

4 Repeat the above contracting against a reasonably heavy weight like a book bag (type and Enter a Mark to annotate your record).

5 Click Stop to halt recording.

6 Select Save in the File menu.

7 Move the electrodes to the (antagonistic) triceps muscle and repeat the above.

Questions

Look at your data:

1. Is the EMG activity greater when moving the book bag than without? What does this tell you about the relationship between motor neuron activity, EMGs and muscle performance and work?
2. When the bag is held at arm s length, is EMG activity constant for the duration of the experiment, or did it increase?
3. With a constant load being lifted, why would muscle activity increase?

Experiment 8: Reflexes and Reaction Times

Overview

During our day-to-day lives we detect changes in the environment and react appropriately. An external stimulus is detected by one or more neurons, which send the sensory information to the central nervous system, where it is processed. If a motor response is initiated, it usually involves a series of action potentials that produce a muscle contraction and a movement of one or more parts of the body. A simple reflex is perhaps the easiest of this type of stimulus-response reaction. A loud sound or something flying at your eye make you blink, while a tap on the tendon under the knee cap produces the knee-jerk (or myotactic) reflex.

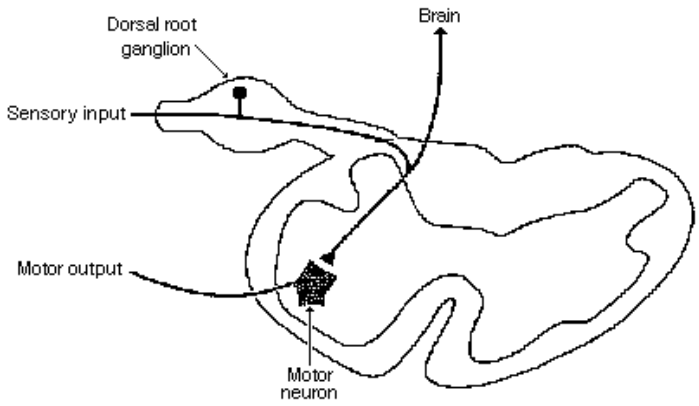

Figure 3-8: A cross section of the spinal cord showing the single synapse between the sensory and the motor neurons involved in the myotactic reflex.

A simple reflex like the myotactic reflex is produced via single synapses between sensory axons and motor neurons. The required circuitry for this reflex is confined to the spinal cord, as shown in Figure 3-8 on page 62. Sensory information also ascends to higher centers, but the brain is not necessary or required to perform the reflex. More complex reflexes usually involve additional (inter-) neurons and more than one population of motor neurons. Thus, more neurons and synapses are involved, which usually results in a longer delay between stimulus and response, and often a more complex response. One example of such a complex response is the flexion withdrawal reflex, where a noxious stimulus to one leg causes withdrawal of the stimulated leg and extension of the other.

In this lab you will study the time taken between a stimulus and the response. These reaction time measurements will be made from a volunteer subjected to harmless visual and sound stimuli. In addition, the effect of priming and prediction will be examined.

Equipment Required

PC computer

ETH-256

Event marker

Plethysmograph

Equipment Setup

1. Connect the ETH-256 unit to the A/D card (described in Chapter 1).
2. Plug the event marker into the DIN8 socket on channel one.
3. Plug the plethysmograph into the DIN8 socket on channel two.
4. The equipment should look like Figure 3-9 on page 63.

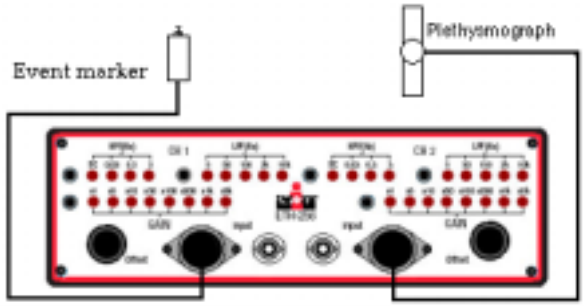

Figure 3-9: The equipment used to measure reaction times from a volunteer.

Start the Software

1. Click the (Windows) Start menu, move the cursor to Programs and then to the iWorx folder and select LabScribe.
2. When the program opens, select Load from the Settings menu.
3. When the dialog box appears, select Human and then click OK.
4. Click on the Settings menu again and select the Muscle #3 settings file.
5. After a short time, LabScribe will appear on the computer screen with the Muscle #3 settings.

Exercise 1: Reaction Time and Sound

Aim: To measure the reaction time of a volunteer to a sound.

Procedure

1. Ask the volunteer to sit in a chair placed in a location so that their back is facing the computer screen with the keyboard immediately behind them.
2. Ask the volunteer to relax and listen as another student taps the white surface of the plethysmograph with a pencil. Ask the volunteer if they can hear the tapping sound.
3. Ask the volunteer to (quickly) click the event marker as soon as they hear the tap.
4. Click Start.
5. Present a total of 10 taps, but make sure that the taps are delivered so that the volunteer cannot predict when the stimulus will be presented.
6. Click Stop to halt recording.
7. Select Save As in the File menu, type a meaningful name and save the file in an appropriate place on the hard drive.

Data Analysis

1. Click the 2 cursor icon (Figure 3-10 on page 65), so that two blue vertical lines appear over the recording window.
2. Drag the cursors left and right so that the large spike on the plethysmograph channel and the signal from the event marker are located between the two blue lines.
3. Click the Analysis icon (Figure 3-10 on page 65) to open the Analysis window.

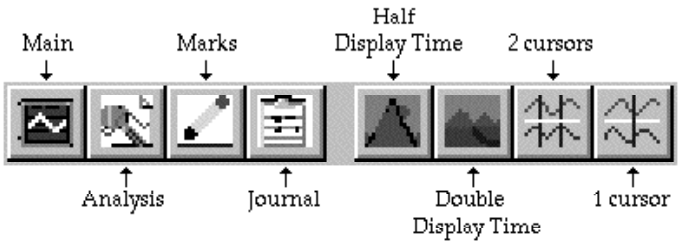

Figure 3-10: The LabScribe toolbar

4. Use the mouse to click and drag one cursor to the beginning of the spike on the plethysmograph channel and the second cursor to the onset of the signal from the event marker (Figure 3-11 on page 65).
5. Enter the time (t2-t1) difference into the Journal either by typing the values directly, or by right clicking in the Analysis window and electing Send Data/Titles to the Journal.
6. Use the scroll bars to scroll through your data in the Analysis window and repeat the measurements for all 10 trials.
7. Omit the longest and shortest values and average the remaining eight values to give the mean reaction time.

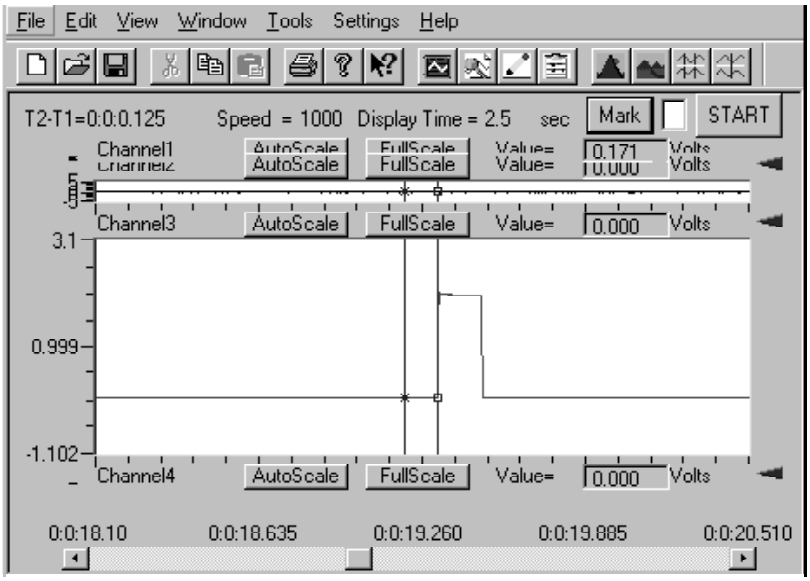

Figure 3-11: Data produced by tapping the plethysmograph which entered a a large spike on CH 2 and produced a sound, which the volunteer used as a cue to press the event marker (trace). The cursors are positioned to measure the reaction time the time between the mark and the first response.

Exercise 2: Reaction Time and Prompted Sounds

Aim: To measure the reaction time of a volunteer to sounds delivered immediately after a verbal prompt.

Procedure

Repeat exercise #1, but ask the volunteer if they are ready immediately prior to tapping the plethysmograph.

Data Analysis

Measure the interval between stimulus and response for each event.

Exercise 3: Reaction Time and Predictable Sounds

Aim: To measure the reaction time of a volunteer to sounds delivered at a predictable interval.

Procedure

Repeat exercise #1, but tap the plethysmograph at a predictable interval.

Data Analysis

Measure the interval between stimulus and response for each event.

Questions

1. Is the average reaction time the same for all three conditions?
2. Does the interval decrease during exercises 2 and 3?

Exercise 4: Reaction Time and Visual Cues

Aim: To measure the reaction time of a volunteer to a visual cue.

Procedure

1. Ask the volunteer to sit in a chair and face the computer screen.
2. Ask the volunteer to watch the screen and (quickly) press the event marker button as soon as they see the trace deflection.
3. Click Start; a second student (out of site) should tap the plethysmograph (and the volunteer should respond).
4. Present a total of 10 trials, but make sure that the events are delivered so that the volunteer cannot predict when the visual cue will be presented.

5 Click Stop to halt recording.

6 Select Save from the File menu.

Data Analysis

Your result should look like Figure 3-11 on page 65.

1 Use the cursor and the marker to measure the time delay between visual stimulus and response.

2 Repeat the measurements for all 10 trials.

3 Omit the longest and shortest values and average the remaining eight values to give the mean reaction time.

Questions

Is the average reaction time comparable to the data from exercise #1? What does this tell you about the time taken to react to oral and visual cues?

Exercise 5: Reflexes

Aim: To examine different reflexes.

The Knee-Jerk Reflex

1 Ask the volunteer to sit in a chair and cross their legs.

2 Firmly strike the tendon below the knee cap and watch the knee jerk.

3 Ask the volunteer to cup and link their hands, and then pull outwards (this is the Jendrassil maneuver). Repeat step #2.

What effect does Jendrassil maneuver have on the knee-jerk reflex. Can you explain why?

The Papillary Reflex

1 Shade the eyes for 30 seconds.

2 Shine a light into one eye. What is the response of the pupil?

3 Repeat steps 1 and 2, but note the response of the unstimulated eye.

What is the effect of light on the eyes? Can you explain why this reflex would be beneficial to you?

The Spinociliary Reflex

1 A student should look into one of the volunteer s eyes.

2 The student should gently stroke the hair in the hair line behind one ear. What is the effect on the pupil?

3 Repeat step #2 but stroke the hair behind the other ear

Can you explain why this reflex would be beneficial to you?

Chapter 4: External Respiration

Overview

Respiration is the process by which the body obtains oxygen and eliminates carbon dioxide. Internal respiration involves the metabolic processes that occur within mitochondria. External respiration, however, describes the exchange of oxygen and carbon dioxide between the cells and the environment. You will examine human breathing in the next three laboratories in a study of external respiration.

The human respiratory system consists of a series of tubes that branch and terminate as clusters of small membranous air sacs called alveoli. Oxygen and carbon dioxide cross the wall of the alveoli between the air and the blood. Factors that influence diffusion include a surface area, diffusion distance, and concentration gradient. The alveoli provide a surface area about the size of a tennis court, and their thin walls provide a short diffusion distance. A high concentration gradient is insured by (1) directing blood with low oxygen and high carbon dioxide levels to the lungs and (2) pulmonary ventilation (breathing), which maintains a high level of oxygen and a low level of carbon dioxide in the alveolar air. Thus, the alveoli and associated blood supply are well suited for the diffusion of oxygen into the blood and carbon dioxide into the alveoli.

Ventilation of the human lung is produced by muscular contraction. The resulting change in thoracic volume is conveyed to the elastic lungs by the fluid-filled pleural cavity. Inspiration is achieved by a contraction of the diaphragm and the intercostal muscles, both of which increase the volume of the thoracic cavity. In the resting individual expiration is usually passive since muscle relaxation and gravity act to decrease thoracic volume. Under certain circumstances, like during exercise, forced expiration is produced by contraction of intercostal muscles.

The amount of air that moves in or out of the lungs during any one breathing cycle is called the tidal volume. This is not the maximum amount of air that can be moved through the lungs (the vital capacity), since there are reserve volumes that can be tapped to

change the tidal volume. While the depth of breathing can be altered in this way, the rate of breathing can also be changed. These two parameters are controlled by the respiratory control center, which is located in the medulla of the brain. The center insures that the exchange of oxygen and carbon dioxide at the lungs takes place at a rate that matches the body's requirements. This is a dynamic process, since the body s requirements change over time. This is the subject of the first laboratory, which examines breathing in a volunteer at rest and immediately after exercise. The second laboratory investigates the effect of gravity on breathing, while the third exercise looks at other factors that influence the rate and depth of breathing.

Experiment 9: Breathing Parameters at Rest and after Exercise

Overview

The amount of air that moves in or out of the lungs during any one breathing cycle is called the tidal volume. After normal inspiration it is possible to breathe in additional air this is called the inspiratory reserve volume. Similarly, after a normal expiration it is possible to exhale additional air from the lungs this is called the expiratory reserve volume. In this latter case, even if the expiratory reserve volume is fully expelled from the lungs, there is still air in the lungs.This non-exhaleable amount of air is called the residual volume. Clearly, this tidal flow of air through the lungs results in the mixing of the fresh air with residual air. Since this residual air has been in the lungs it has a lower oxygen level and higher carbon dioxide level than fresh air. It is, therefore, not surprising that air in the alveoli is a mixture of stale and fresh air.

The respiration center in the medulla insures that gaseous exchange at the lung matches the requirements of the body. During times of increased demand the tidal volume can be increased, using some of the reserve lung volumes, to bring more fresh air into the body. In addition, the rate of breathing and the rate of air movement into and out of the lungs can be changed. In this lab you will measure these parameters in a volunteer at rest and immediately after exercise, when the body s demands for oxygen have been elevated.

Equipment Required

PC computer

ETH-256 and A/D Card

Spirometer flow head and plastic tubes

SP-100, spirometer unit with cable

Equipment Setup

1. Connect the ETH-256 unit to the A/D card (described in Chapter 1).
2. Firmly push the two air flow tubes into the two outlets on the flow head.
3. Firmly push the other ends of the two air flow tubes into the two outlets on the SP-100 spirometer unit.
4. Use the cable to connect the output on the spirometer unit to the input on channel one of the ETH-256 (Figure 4-1 on page 71).

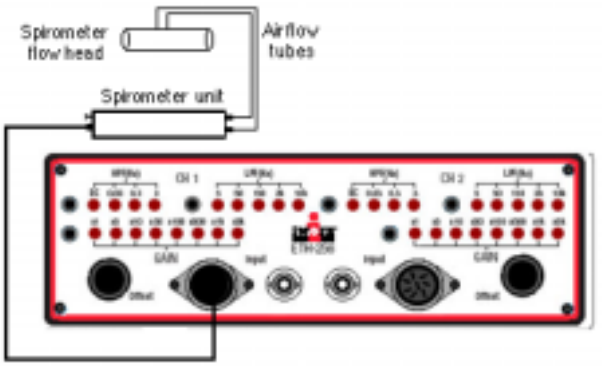

Figure 4-1: Connect the spirometer to the ETH-256 unit.

5. Set the controls on the ETH-256 as follows:

	Ch. 1: Spirometer Pod	Ch. 2: No Device
Gain	x1	x1
High Pass	DC	DC
Low Pass	50Hz	50Hz

Start the Software

1. Click the (Windows) Start menu, move the cursor to Programs and then to the iWorx folder and select LabScribe.
2. When the program opens, select Load from the Settings menu.
3. When the dialog box appears, select Human and then click OK.
4. Click on the Settings menu again and select the Lung #1 settings file.
5. After a short time, LabScribe will appear on the computer screen with the Lung #1 settings.

Before Starting

1. The spirometer will monitor breathing from a volunteer. It is important that the volunteer is healthy and has no history of respiratory or cardiovascular problems.
2. The tubes on the flow head should always be in the upright position, to avoid problems with condensation.
3. Turbulent air flow through the flow head will produce a noisy signal.To avoid turbulent air flow be sure that the flow head opening is well inside of the mouth. Remember that air that enters or leaves through the nose is not counted in the volume calculation and will cause errors in the reading
4. The spirometer will display flow on channel one. The software is set to integrate the data you are recording on channel one and display it as a volume on channel two. The LabScribe software will report volume in liters on channel two using a conversion factor of 150 mVsec/liter. If the calibration number written on the spirometer serial number tag is larger or smaller (by more than 10%) than 150mV sec/liter you may have to recalibrate channel two. Check to be sure that the software is set to integrate the flow data by moving the mouse to place the cursor over channel two, right click the mouse and check that the Integrate option is checked. If it is not checked, select it now.

Exercise 1: Breathing in a Resting Volunteer

Aim: To measure breathing parameters in a resting individual.

Procedure

1. The volunteer should hold the spirometer head with the air flow tubes up. Breath normally this is difficult when you think about it! The volunteer should sit quietly and become accustomed to breathing through the spirometer.
2. With the resting volunteer breathing normally through the spirometer, click Start, type resting and press Enter on the keyboard.

Note: *The LabScribe software does a zero calibration during the first second of recording. No air should be moving through the flow head during this time.*

3. Click AutoScale in the channel one title area. Notice the slow wave on channel two as the volunteer breathes in and out.
4. Type InMax, ,ask the volunteer to inhale as much as possible and press Enter on the keyboard. Quickly type OutMax, ,ask the volunteer to exhale as much as possible and press Enter on the keyboard. The volunteer should return to normal breathing through the spirometer.
5. Click Stop to halt recording.

6 Select Save As in the File menu, type a meaningful name and save the file in an appropriate place on the hard drive.

Data Analysis - Measurements

Your data may look something like Figure 4-2 on page 73.

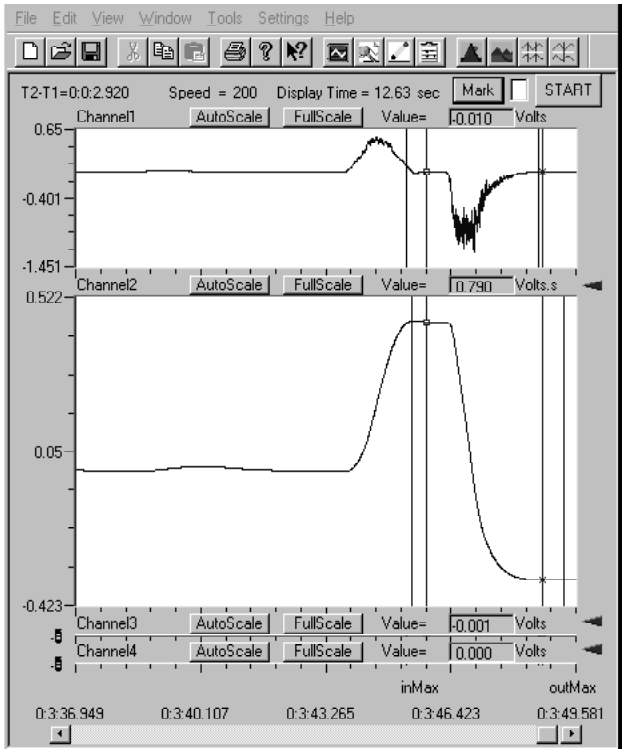

Figure 4-2: A recording in the Main window from a resting volunteer breathing through the spirometer (upper trace) and its integral (lower trace). The trace shows a normal breathing cycle (left) and then a forced inspiration and expiration (right).

1 Click the 2 cursor icon (Figure 4-3 on page 74), so that two blue vertical lines appear over the recording window.

2 Adjust the Display Time (Figure 4-3 on page 74) if necessary, drag the cursors left and right so that at least one breathing cycle is located between the two blue lines.

3 Click the Analysis icon (Figure 4-3 on page 74) to open the Analysis window.

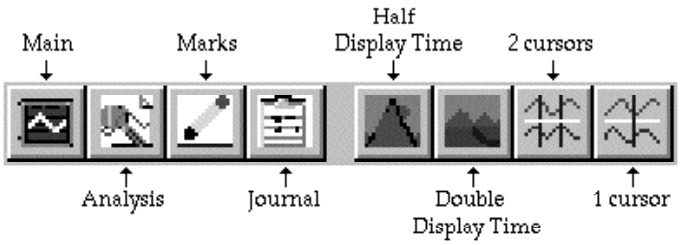

Figure 4-3: The LabScribe toolbar

4 Use the mouse to click and drag the two cursors to measure, for each of the 5 breathing cycles (prior to the forced inhale and exhale):

¥ Tidal volume (TV): amplitude of each of the five breathing cycles (base to peak as shown in Figure 4-4 on page 74); average the five voltage values;

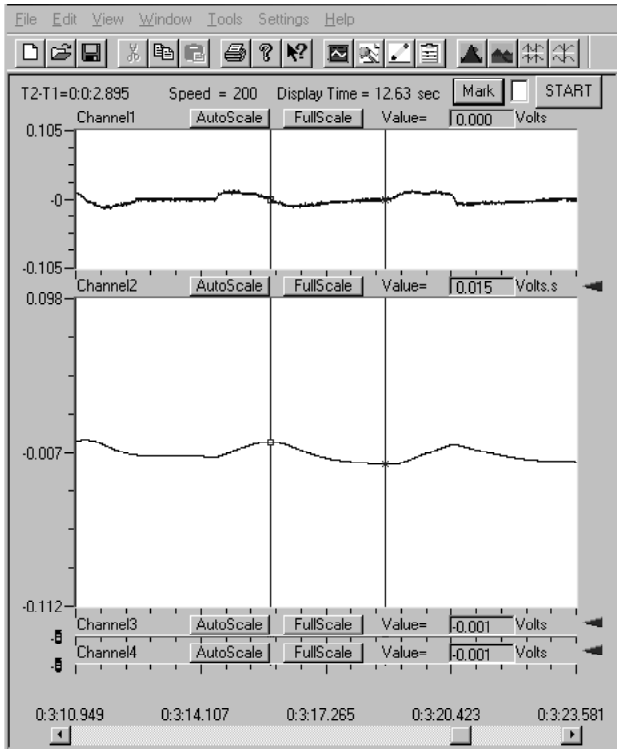

Figure 4-4: The spirometer signal (upper trace) and its integral (lower trace) recorded from a resting volunteer and displayed in the Main window; an upward deflection of the upper trace represents inspiration. The cursors are positioned on the peak and trough of the integrated signal to measure the tidal volume

¥ The duration of each of the five breathing cycles is easiest to measure from peak to peak in the air flow record (channel two) as shown in Figure 4-5 on page 75; average the five values to obtain the mean time taken for each breath.

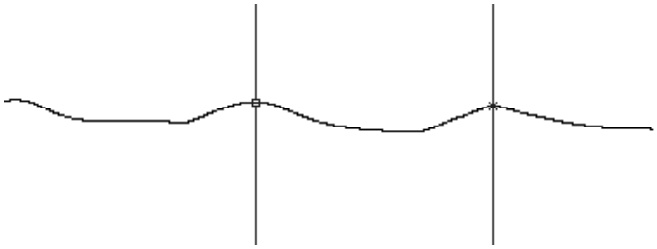

Figure 4-5: The integral of the spirometer signal recorded from a resting volunteer and displayed in the Main window. The cursors are positioned on the peaks of successive signals to measure the time interval.

¥ The maximum rate of air movement during exhalation from the lung volume recorded on channel three.

Place the marker and the cursor on the steepest part of the curve recorded during inhalation (Figure 4-6 on page 75). Read the rate of change of volume (v2-v1) at the top of the Analysis window and divide this value by time (t2-t1). Calculate the average of the five calculated values and enter your data in the Journal.

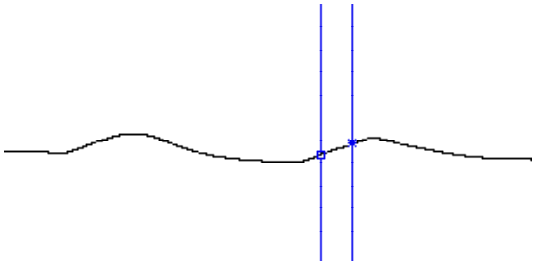

Figure 4-6: The integral of the spirometer signal recorded from a resting volunteer. The cursors are positioned on the steepest part of the inspiration slope.

¥ The maximum rate of air movement during inhalation is similar to the preceding bullet, except the markers are placed on the steepest portion of the exhalation curve.

5 Use the markers to measure the tidal (TV) inspiratory reserve (IR) and expiratory reserve (ER) volumes and the vital capacity (VC) (Figure 4-7 on page 76).

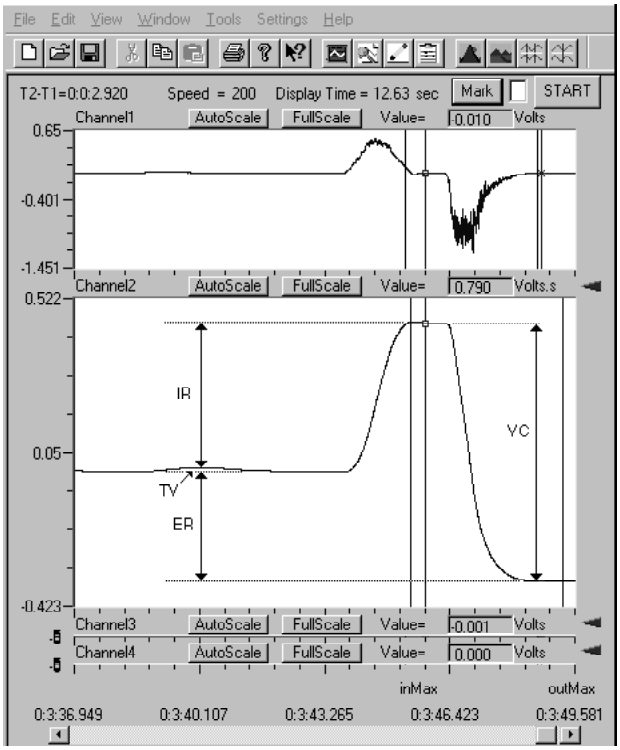

Figure 4-7: A recording in the Main window from a resting volunteer breathing through the spirometer (upper trace) and its integral (lower trace). The trace shows a normal breathing cycle (left) and then a forced inspiration and expiration (right); labels show tidal volume (TV), inspiratory reserve volume (IR), expiratory reserve volume (ER) and vital capacity (VC). Calculate mean values for each.

Data Analysis - Calculations

1 Use the mean duration of the breathing cycles to measure breathing rate:

$$\text{Breathing rate} = \frac{60 \text{ breaths/minute}}{\text{mean duration (s)}}$$

2 Multiply the mean tidal volume (#2) by the breathing rate to calculate the volume of air passing in and out of the resting volunteer s lungs each minute.

Data Analysis - Tabulation

Tabulate your data as follows:

Air flow (mV/s)		Lung volumes (l)			Rate	Time/	Total air
inhale	exhale	TV	IR	ER	VC	(breaths/m)	breath	flow /m
Resting:								

Exercise 2: Breathing Parameters from other Students

Aim: To measure breathing parameters in all students.

Procedure

1. Wash the spirometer head and wring dry. Be careful not to touch the membrane inside of the flow head.
2. Repeat Exercise #1, labeling each segment of file with the student s name.
3. Select Save in the File menu.
4. Measure the lung volumes for each student.

Questions

1. Are the lung volumes the same in all students?
2. Combine class data to see whether there is any correlation between tidal volume or vital capacity and sex, smoking or apparent fitness?

Exercise 3: Breathing in the Volunteer Immediately after Exercise

Aim: To measure breathing parameters after exercise.

Procedure

1. Attach a clean spirometer head.
2. The volunteer should exercise sufficiently enough to elevate breathing rate, but with minimal class disruption. Running up and down flights of stairs is a good method.
3. The volunteer should immediately sit down, hold the spirometer by the grip and place the mouthpiece in the mouth.
4. Quickly click Start, type after exercise, and press Enter on the keyboard.
5. After about five breathing cycles, ask the volunteer to inhale as much as possible and then exhale as much as possible type comments and press Enter on the keyboard if possible.
6. Click Stop to halt recording.
7. Select Save in the File menu.

Data Analysis

Repeat as for Exercise 1 and tabulate your data as follows:

	Air flow (ml/s)		Lung volumes (l)				Rate	Time/	Total
air	inhale	exhale	TV	IR	ER	VC	(breaths/m)	breath	flow/m
Resting:									
Exercise:									

Questions:

1. Did tidal volume change after exercise?
2. Did exercise influence the time taken for each breathing cycle?
3. Did the rate of air flow during the inhaling phase increase with exercise how can you account for this?
4. Did the rate of air flow during the exhaling phase increase with exercise **/*+-how can you account for this?
5. Did the volume of air passing in and out of the resting volunteer s lungs each minute increase due to exercise? If so, was this due to an increase in the rate of breathing, the depth of breathing (tidal volume) or a combination of both factors?
6. Did exercise influence the vital capacity of the individual?
7. If the tidal volume changed due to exercise, can this be accounted for by changes in the TV, IR, the ER, or some combination of both?

Experiment 10: Breathing and Gravity

Overview

Over the long term, the amount of oxygen (O2) taken up and carbon dioxide (CO2) discharged by the tissues is matched with the amount of O2 taken up and CO2 discharged at the lungs. Changes in the demands made by the body cause the respiratory control center in the medulla to change the depth and rate of breathing. This was seen in the last laboratory when the effect of exercise was examined.

The exchange of O2 and CO2 at the lungs relies upon diffusion between the air and the blood. Any change in the rate of diffusion could produce a change in breathing parameters. One factor that influences the rate of diffusion is surface area. All else being equal, an increase in the surface area will increase the rate of diffusion and thus decrease the rate and depth of breathing. This will be examined in this lab.

Gaseous exchange between the alveolar air and the blood takes place at the pulmonary capillaries. These thin-walled vessels are distensible and easily collapse. The diameter of the pulmonary capillaries is determined by the transmural pressure the pressure difference between the inside (blood pressure) and the outside (alveolar pressure) of the vessel. If the pressure in the alveoli is greater than the blood pressure the pulmonary capillaries will collapse and blood will not flow through them. Under these conditions, while the diffusion gradients may be present for the exchange of O2 and CO2 between the air and the blood, the collapsed vessels will preclude any gaseous exchange.

In this lab you will examine the effects of gravity on breathing, first by observing the effects on peripheral circulation in the finger, and then by measuring the different lung volumes during normal breathing in a resting volunteer who is standing and then lying down.

Equipment Required

PC computer

ETH-256 and National Instruments A/D Card

Spirometer flow head and plastic tubes

SP-100, spirometer unit with cable

Plethysmograph

Equipment Setup

1. Connect the ETH-256 unit to the A/D card (described in Chapter 1).
2. Firmly push the two air flow tubes into the two outlets on the flow head.
3. Firmly push the other ends of the two air flow tubes into the two outlets on the SP-100 spirometer unit.
4. Use the cable to connect the output on the spirometer unit to the input on channel two of the ETH-256 hardware (Figure Figure 4-8 on page 80).
5. Untangle the plethysmograph cable.
6. Place the plethysmograph on the volar surface (where the fingerprints are located) of the distal segment of a middle finger; wrap the Velcro to attach the unit firmly to the end of the finger.

7 Push the DIN 8 plug on the other end of the cable into the socket labeled channel one (Figure 4-8 on page 80).

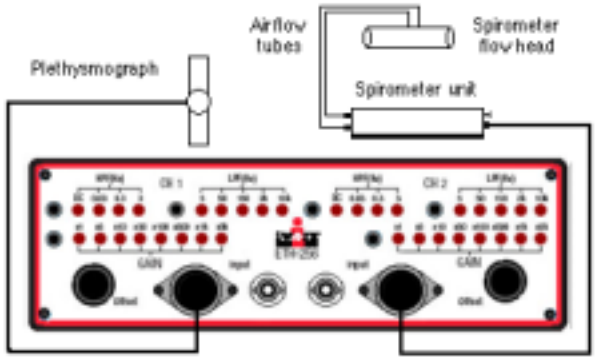

Figure 4-8: Attach the spirometer and plethysmograph to the ETH-256.

8 Set the controls on the ETH-256 as follows

	Ch. 1: Plethysmograph	Ch. 2: Spirometer pod
Gain	x10	x1
High Pass	DC	DC
Low Pass	50Hz	50Hz

Start the Software

1 Click the (Windows) Start menu, move the cursor to Programs and then to the iWorx folder and select LabScribe.

2 When the program opens, select Load from the Settings menu.

3 When the dialog box appears, select Human and then click OK.

4 Click on the Settings menu again and select the Lung #2 settings file.

5 After a short time, LabScribe will appear on the computer screen with the Lung #2 settings.

Before Starting

1 The spirometer will monitor breathing from a volunteer. It is important that the volunteer is healthy and has no history of respiratory or cardiovascular problems.

2 The tubes on the flow head should always be in the upright position, to avoid problems with condensation.

3 Turbulent air flow through the flow head will produce a noisy signal.To avoid turbulent air flow, be sure that the flow head opening is inside of the mouth. Remember that air that enters or leaves through the nose is not counted in the volume calculation and will cause errors in the reading

4 The spirometer will display flow on channel two. The software is set to integrate the data on channel two and display it as a volume on channel three. The LabScribe software will report volume in liters on channel three using a conversion factor of 150 mVsec/liter. If the calibration number written on the spirometer serial number tag is larger or smaller (by more than 10%) than 150mVsec/liter you may have to recalibrate channel three. Check to be sure that the software is set to integrate the flow data by moving the mouse to place the cursor over channel three, right click the mouse and check that the Integrate option is checked. If it is not checked, select it now.

Exercise 1: The Effects of Gravity on Peripheral Circulation

Aim: To study the effects of gravity on blood circulation in the finger.

Procedure

1 The volunteer should sit quietly with their hands in their lap.

2 Click Start and record the finger pulse.

3 Click AutoScale in the channel one title area and see the rhythmic finger pulse signal get bigger. Type hands in lap and press Enter on the keyboard.

4 The volunteer should then place both hands on their head; type hands on head and press Enter on the keyboard.

5 The volunteer should then reach both hands as high as possible (don t stretch the cable); type hands high and press Enter on the keyboard.

6 Click Stop to halt recording.

7 Select Save As in the File menu, type a meaningful name and save the file in an appropriate place on the hard drive.

Data Analysis

1 Use the arrows at the bottom of the window to scroll to the beginning of the recording.

2 Click the 2 cursor icon (Figure 4-9 on page 82), so that two blue vertical lines appear over the recording window.

3 Drag the cursors left and right to place them between the first five or so finger pulse signals.

4 Click the Analysis icon (Figure 4-9 on page 82) to open the Analysis window.

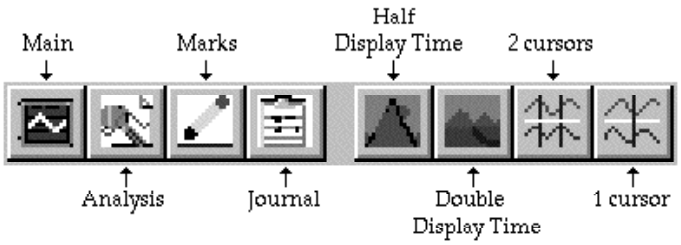

Figure 4-9: The LabScribe toolbar

5 Click to de-select channels two and three.

6 Click and drag the cursors left and right on channel one to place one on the baseline before the first signal and the second at the peak of the signal (Figure 4-10 on page 82). Read off the peak blood flow from the resting volunteer as the voltage difference (v2-v1). Right click the mouse and select to enter the title and then the data into the Journal label as data from volunteer with hands in lap.

7 Repeat with data obtained in the other two hand positions.

8 Click the Journal icon (Figure 4-9 on page 82) and label the average value for blood flow in the different hand positions.

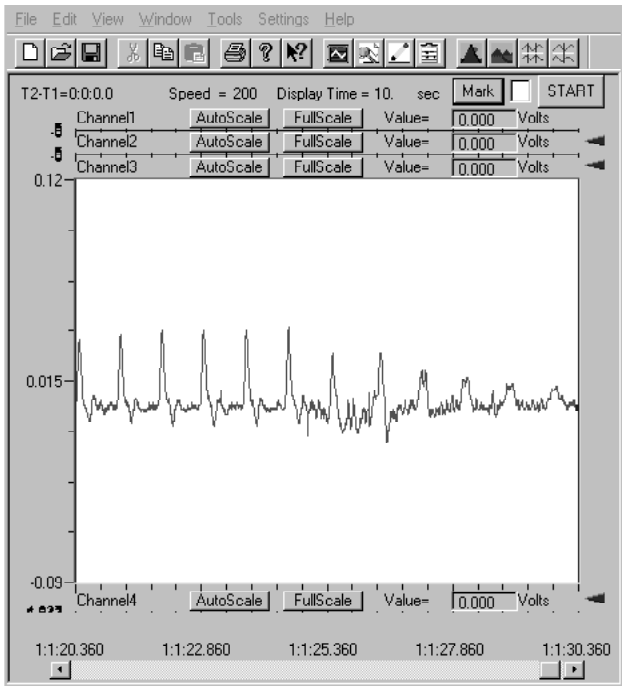

Figure 4-10: A recording from the plethysmograph in the Main window where the hands located in the volunteer s lap (left) were raised above the head (right).

Questions

1. What happens to the size of the finger pulse when the hands are raised?
2. If the size of the finger pulse signal indicates blood pressure, what do you think happens to blood pressure in the fingers when the hands are raised over the head?

Exercise 2: Breathing when Standing (or sitting)

Aim: To study and measure various breathing parameters in an erect volunteer.

Equipment Setup

Disconnect the plethysmograph from the ETH-256 unit by removing the DIN8 plug from channel one.

Procedure

1. The volunteer should hold the spirometer head with the air flow tubes up. Breath normally this is difficult when you think about it! The volunteer should sit or stand quietly and become accustomed to breathing through the spirometer.
2. Click Start and record the rhythmic signal produced by the volunteer s breathing. Type standing (or sitting) and press Enter on the keyboard.

Note: *The LabScribe software does a zero calibration during the first second of recording. No air should be moving through the flow head during this time.*

3. After five breathing cycles ask the volunteer to inhale as much as possible (type inhale and press Enter on the keyboard) and then exhale as much as possible (type exhale and press Enter on the keyboard).
4. Click Stop to halt recording.
5. Select Save in the File menu.

Data Analysis - Measurements

For each of the five breathing cycles (prior to the forced inhale and exhale) use the two cursors to measure:

The Tidal Volume

1. Use the arrows at the bottom of the window to scroll to the beginning of this section of the recording.
2. Click the 2 cursor icon (Figure 4-9 on page 82), so that two blue vertical lines appear over the recording window.
3. Drag the cursors left and right to place them between the first two breathing cycles.

4 Click the Analysis icon (Figure 4-9 on page 82) to open the Analysis window.

5 Click to de-select channels one and four.

6 Click and drag the cursors left and right on channel three to place one on the trough of the signal and the other on the peak (Figure 4-11 on page 84). Read off the tidal volume from channel three in the resting volunteer as the voltage difference (v2-v1). Right click the mouse and select to enter the title and then the data into the Journal.

7 Scroll through your record in the Analysis window and repeat the above measurement for all breathing cycles.

8 Click the Journal icon (Figure 4-9 on page 82), label your data as a recording of tidal volume from a resting individual and calculate the average tidal volume value.

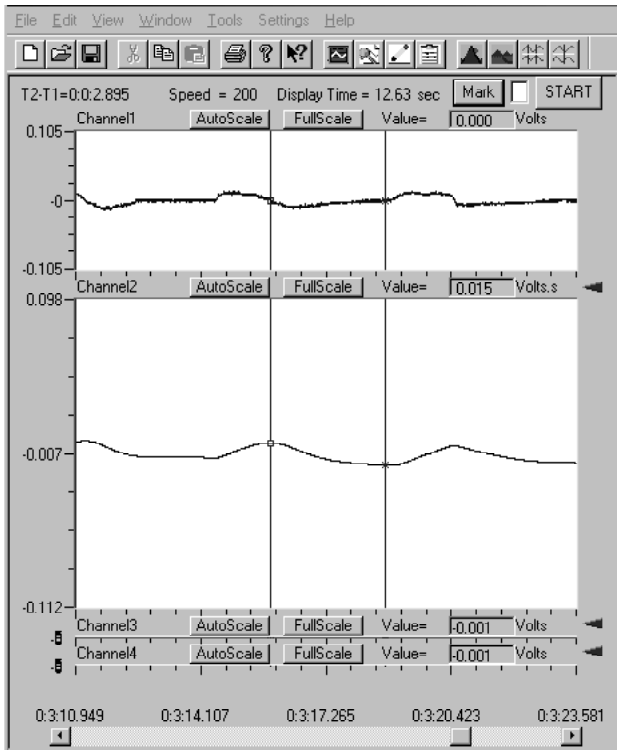

Figure 4-11: The spirometer signal (upper trace) and its integral (lower trace) recorded from a resting volunteer and displayed in the Main window; an upward deflection of the upper trace represents inspiration. The cursors are positioned on the peak and trough of the integrated signal to measure the tidal volume (0.015 volts in this example).

The (time) duration of each of the five breathing cycles.

1 Proceed as above, except the time (t2-t1) between adjacent peaks Figure 4-12 on page 85.

2 Click the Journal icon (Figure 4-9 on page 82), label your data as a recording of tidal volume from a resting individual and calculate the average tidal volume value.

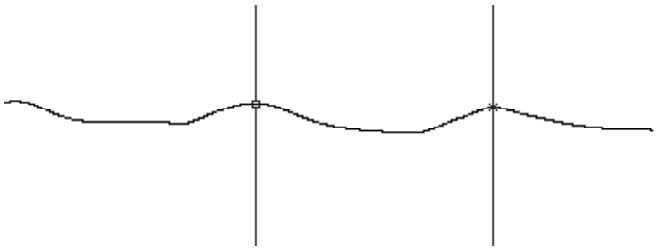

Figure 4-12: The integral of the spirometer signal recorded from a resting volunteer and displayed in the Main window. The cursors are positioned on the peaks of successive signals to measure the time interval.

Air Movement

1 Use the arrows at the bottom of the window to scroll to the beginning of the recording.

2 Click and drag the cursors left and right on channel three to place them on the steepest portion of the inhalation curve (Figure 4-13 on page 85). Read off the peak rate of air flow during exhalation in the resting volunteer as the voltage difference (v2-v1). Right click the mouse and select to enter the title and then the data into the Journal.

3 Scroll through your record in the Analysis window and repeat the above measurement for all breathing cycles.

4 Click the Journal icon (Figure 4-9 on page 82), label your data as a recording of tidal volume from a resting individual and calculate the average tidal volume value.

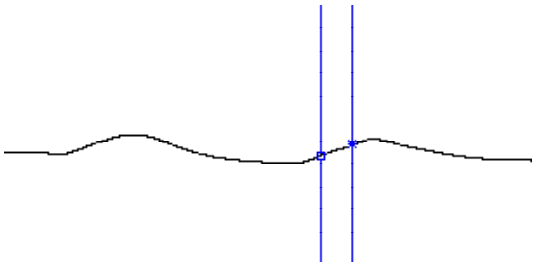

Figure 4-13: The integral of the spirometer signal recorded from a resting volunteer.

The cursors are positioned on the steepest part of the inspiration slope.

Data Analysis - Calculations

1 Use the mean duration of the breathing cycles to measure breathing rate:

$$\text{Breathing rate} = \frac{60 \text{ breaths/minute}}{\text{mean duration (s)}}$$

2 Multiply the mean tidal volume (#2) by the breathing rate (#1) to calculate the volume of air passing in and out of the resting volunteer s lungs each minute.

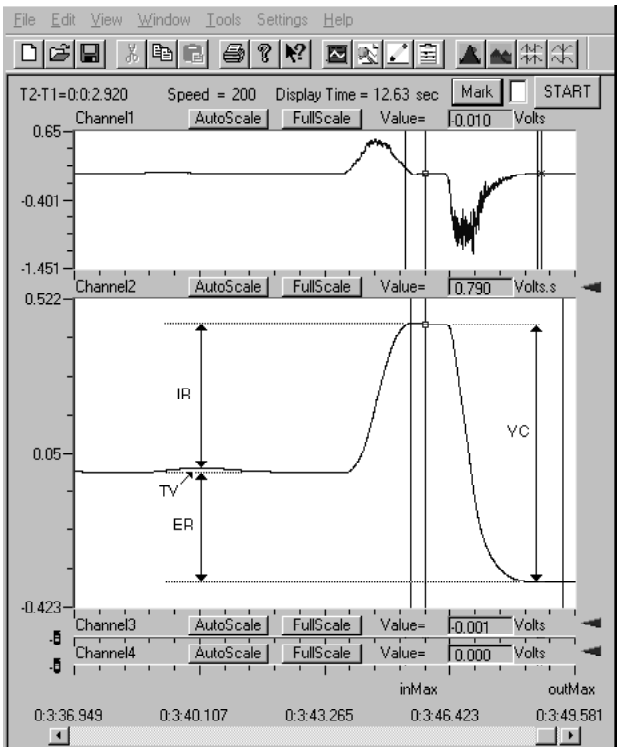

Figure 4-14: A recording in the Main window from a resting volunteer breathing through the spirometer (upper trace) and its integral (lower trace). The trace shows a normal breathing cycle (left) and then a forced inspiration and expiration (right); labels show tidal volume (TV), inspiratory reserve volume (IR), expiratory reserve volume (ER) and vital capacity (VC). Calculate mean values for each.

Data Analysis - Tabulation

Tabulate your data as follows:

Air flow (ml/s)		Lung volumes (l)			Rate	Time/	Total air
inhale	exhale	TV	IR	ER	VC	(breaths/m)	breath	flow/m

Erect:

Exercise 3: Breathing when Lying Down (face up)

Aim: To study and measure various breathing parameters in a volunteer who is lying down.

Procedure

1. The volunteer should lie down on their back and relax.
2. As before, the volunteer should not be disturbed and should be relaxed and accustomed to breathing through the spirometer.
3. Click Start, type lying down and press Enter on the keyboard.
4. After about five breathing cycles ask the volunteer to inhale as much as possible and then exhale as much as possible type comments and press Enter on the keyboard.
5. Click Stop to halt recording.
6. Select Save in the File menu.

Data Analysis

Repeat as for Exercise 2 and tabulate your data as follows:

	Air flow (ml/s)		Lung volumes (l)			Rate	Time/	Total air
	inhale	exhale	TVIR	ER	VC	(breaths/m)	breath	flow/m
Erect:								
Lying								

Questions

1. What effect does lying down have on the total amount of air breathed into the lungs/minute?
2. What effect does lying down have on the various lung volume?
3. Examining tidal volume, what is the effect of lying down?
4. From your analysis of data on finger pulse, what is the effect of raising your hand on blood pressure?
5. With this answer in mind, in the standing individual would the blood pressure be the same in the pulmonary capillaries at the base of the lung and the apex (top) of the lung? Which would have the lower blood pressure?
6. With this answer in mind, if you assume that the lower the blood pressure the more likely those pulmonary capillaries are to be collapsed, where in the lung would you expect there to collapsed capillaries at the base or at the apex?

7 If some capillaries are collapsed, what would be the functional effect of this on the surface area for the diffusion of O2 and CO2?

8 Now, in the individual who is lying down. Would you expect such a dramatic influence on the blood pressure in this position?

9 If the blood pressure is about the same in all pulmonary capillaries would you expect the capillaries to be collapsed?

10 If all pulmonary capillaries are open when lying down, what would be the functional effect of this on the surface area for the diffusion of O2 and CO2?

11 Considering the two body positions, if the demands for O2 and CO2 are the same, what should be the effect on tidal volume and breathing rate? Do you see this?

12 Can you predict any differences in the levels of O2 and CO2 in the exhaled air of people standing and lying down?

Experiment 11: Factors that Effect Breathing Patterns

Overview

The respiratory control center in the medulla is responsible for matching the amount of O2 used by, and CO2 produced at, the tissues with the amount of O2 taken up and CO2 discharged at the lungs. Lung ventilation can be influenced by many factors, including emotion, speech, disease, and the body s position relative to gravity. This latter factor was the focus of the last exercise. In this lab you will examine other factors that influence breathing as well as the effect of breathing on cardiac function.

Equipment Required

PC computer

ETH-256 and National Instruments A/D Card

Disposable spirometer flow head and plastic tubes

SP-100DH, spirometer unit with cable

Plethysmograph

Needle and thread

Equipment Setup

1. Connect the ETH-256 unit to the A/D card (described in Chapter 1).
2. Firmly push the two air flow tubes into the two outlets on the flow head.
3. Firmly push the other ends of the two air flow tubes into the two outlets on the SP-100 spirometer unit.
4. Use the cable to connect the output on the spirometer unit to the input on channel two of the ETH-256 (Figure 4-15 on page 89).

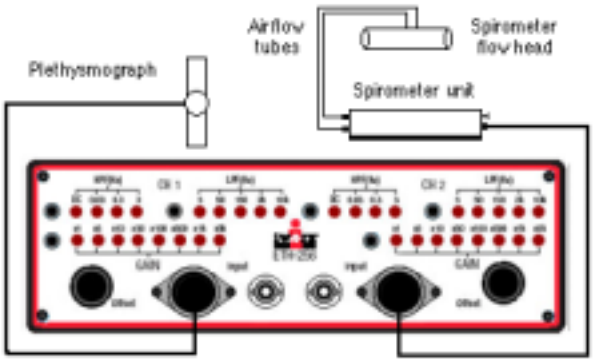

Figure 4-15: Attach the spirometer and Plethysmograph to the ETH -256 unit.

5. Set the controls on the ETH-256 as follows:

	Ch. 1: Plethysmograph	Ch. 2: Spirometer Pod
Gain	x10	x1
High Pass	DC	DC
Low Pass	50Hz	50Hz

Start the Software

1. Click the (Windows) Start menu, move the cursor to Programs and then to the iWorx folder and select LabScribe.
2. When the program opens, select Load from the Settings menu.
3. When the dialog box appears, select Human and then click OK.
4. Click on the Settings menu again and select the Lung #3 settings file.
5. After a short time, LabScribe will appear on the computer screen with the Lung #3 settings.

Before Starting

1. The spirometer will monitor breathing from a volunteer. It is important that the volunteer is healthy and has no history of respiratory or cardiovascular problems.
2. The tubes on the flow head should always be in the upright position, to avoid problems with condensation.
3. Turbulent air flow through the flow head will produce a noisy signal.To avoid turbulent air flow, be sure that the flow head opening is inside of the mouth. Remember that air that enters or leaves through the nose is not counted in the volume calculation and will cause errors in the reading
4. The spirometer will display air flow on channel two. The software is set to integrate the data you are recording on channel two and display it as a volume on channel three. The LabScribe software will report volume in liters on channel three using a conversion factor of 150 mVsec/liter. If the calibration number written on the spirometer serial number tag is larger or smaller (by more than 10%) than 150mVsec/liter you may have to recalibrate channel three. Check to be sure that the software is set to integrate the flow data by moving the mouse to place the cursor over channel three, right click the mouse and check that the Integrate option is checked. If it is not checked, select it now.

Exercise 1: Coughing.

Aim: To study the any changes in breathing patterns due to coughing.

Procedure

1. The volunteer should hold the spirometer head with the air flow tubes up. Breath normally this is difficult when you think about it! The volunteer should sit quietly and become accustomed to breathing through the spirometer.
2. Click Start and record the rhythmic signal produced by the volunteer s breathing. Type resting and press Enter on the keyboard.
3. After about five breathing cycles ask the volunteer to cough (type cough and press Enter on the keyboard).
4. Click Stop to halt recording.
5. Select Save As in the File menu, type a meaningful name and save the file in an appropriate place on the hard drive.

Data Analysis - Measurements

Tidal Volume

1. Use the arrows at the bottom of the window to scroll to the beginning of the recording.
2. Click the 2 cursor icon (Figure 4-16 on page 91), so that two blue vertical lines appear over the recording window.

3 Drag the cursors left and right to place them between the first two breathing cycles.

4 Click the Analysis icon (Figure 4-16 on page 91) to open the Analysis window.

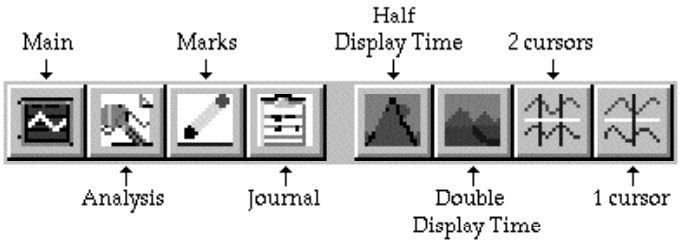

Figure 4-16: The LabScribe toolbar

5 Click to de-select channels one and two.

6 Click and drag the cursors left and right on channel three to place one on the trough of the signal and the other on the peak (Figure 4-17 on page 92). Read off the tidal volume from channel three in the resting volunteer as the voltage difference (v2-v1). Right click the mouse and select to enter the title and then the data into the Journal.

7 Scroll through your record in the Analysis window and repeat the above measurement for all breathing cycles.

8 Click the Journal icon (Figure 4-16 on page 91), label your data as a recording of tidal volume from a resting individual and calculate the average tidal volume value.

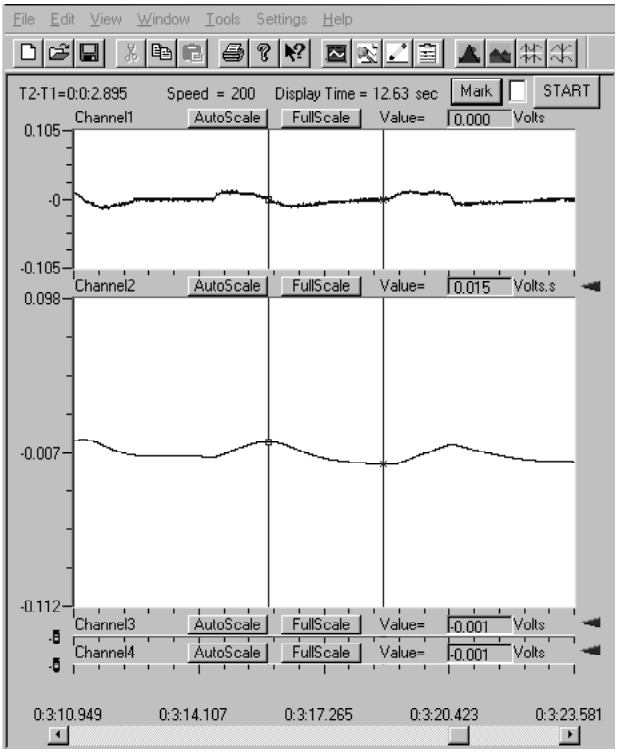

Figure 4-17: The spirometer signal (upper trace) and its integral (lower trace) recorded from a resting volunteer and displayed in the Main window; an upward deflection of the upper trace represents inspiration. The cursors are positioned on the peak and trough of the integrated signal to measure the tidal volume

Air Movement

1. Use the arrows at the bottom of the window to scroll to the beginning of the recording.
2. Click and drag the cursors left and right on channel three to place one on the baseline and the other on the peak of the signal (Figure 4-18 on page 93). Read off the peak rate of air flow during exhalation in the resting volunteer as the voltage difference (v2-v1). Right click the mouse and select to enter the title and then the data into the Journal.
3. Scroll through your record in the Analysis window and repeat the above measurement for all breathing cycles.
4. Repeat with the air flow seen during the cough.
5. Repeat these measurements for inhalation, using the downward deflections in channel three.

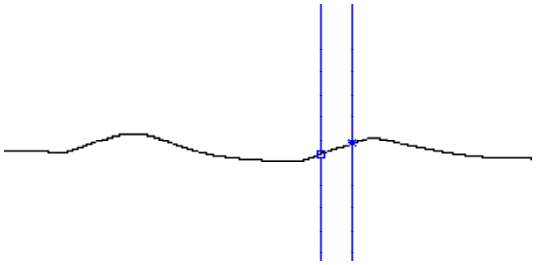

Figure 4-18: The integral of the spirometer signal recorded from a resting volunteer. The cursors are positioned on the steepest part of the inspiration slope.

Questions

1. What phase of the breathing cycle (exhale or inhale) immediately precedes the cough?
2. Does the tidal volume change during the cough?
3. If so, look at your data and determine if the tidal volume changed by changing the amount of air inhaled, exhaled, or some combination of both?
4. Compare the speed of air flow during a normal exhale and the cough. Which is faster?

Exercise 2: Concentration

Aim: To study any changes in breathing patterns due to concentration.

Procedure

1. Push the tip of a needle firmly into a piece of wax or an eraser. Place the needle close to the volunteer perhaps on the bench top or the top of the computer monitor.
2. The volunteer should hold the spirometer in one hand and a piece of thread in the other. As before, the volunteer should not be disturbed and should be relaxed and accustomed to breathing through the spirometer.
3. Click Start and record the rhythmic signal produced by the volunteer s breathing. Type resting and press Enter on the keyboard.

Note: *The LabScribe software does a zero calibration during the first second of recording. No air should be moving through the flow head during this time.*

4. After about five breathing cycles ask the volunteer to try to thread the needle type concentration and press Enter on the keyboard; type through and press Enter on the keyboard when the needle has been threaded.
5. Click Stop to halt recording.

6 Select Save in the File menu.

Data Analysis

As described above, use the two cursors to measure:

¥ The tidal volume: the amplitude of each breathing cycle (Figure 4-17 on page 92) from channel two before, during and after threading the needle.

¥ The rate of air movement/second during inhalation before and after threading the needle (Figure 4-19 on page 94).

¥ The rate of air movement/second during exhalation before and while threading the needle (Figure 4-18 on page 93).

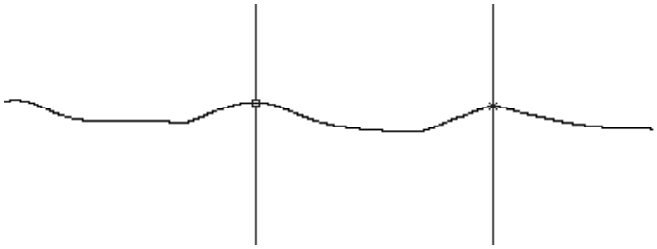

Figure 4-19: The integral of the spirometer signal recorded from a resting volunteer and displayed in the Main window. The cursors are positioned on the peaks of successive signals to measure the time interval.

¥ The (time) duration of each of the five breathing cycles measure the duration from peak to peak in the air flow record (channel two) as shown in Figure 4-19 on page 94.

Questions

1 Which breathing parameters change during the time when fine motor control is required?

2 Can you explain your observations?

Exercise 3: Sitting Up

Aim: To study any changes in breathing patterns when sitting up.

Procedure

1 The volunteer should lie down on their back and relax.

2 As before, the volunteer should not be disturbed and should be relaxed and accustomed to breathing through the spirometer.

Note: *The LabScribe software does a zero calibration during the first second of recording. No air should be moving through the flow head during this time.*

3 Click Start, type lying down and press Enter on the keyboard.

4 Allow the volunteer to breathe about five complete cycles, type sit up when inhaling and press Enter on the keyboard as the volunteer sits up during the inhaling phase.

5 The volunteer should lie down on their back and relax. Repeat the above, but make the request to sit up the exhaling phase of the breathing cycle.

6 Click Stop to halt recording.

7 Select Save in the File menu.

Data Analysis

Do the breathing patterns change immediately before and during the time when the volunteer is sitting up?

Exercise 4: Increasing the Length of the Airways

Aim: To study any changes in breathing patterns when the volunteer breathes through a plastic tube.

Procedure

1 The volunteer should sit in a chair. As before, the volunteer should not be disturbed and should be relaxed and accustomed to breathing through the spirometer.

2 Click Start, type resting and press Enter on the keyboard. Allow the volunteer to breathe about five complete cycles.

Note: *The LabScribe software does a zero calibration during the first second of recording. No air should be moving through the flow head during this time.*

3 Place a length of plastic tubing on the spirometer and record about 10 breathing cycles; type breathing through a tube , and press Enter on the keyboard.

4 Click Stop to halt recording.

5 Select Save in the File menu.

Data Analysis

Use the two cursors in the Analysis window to measure the tidal volume (Figure 4-17 on page 92), the maximum rate of inhalation and exhalation (Figure 4-18 on page 93), and the frequency of breathing (Figure 4-19 on page 94) before and after the tube is attached. Type labels and enter your data into the Journal. Do these parameters change?

Questions

1. Do you think the oxygen requirements of the volunteer changed dramatically when the tube was attached?
2. Where does gaseous exchange take place in the lungs?
3. Does gaseous exchange occur across the walls of the airways (trachea, bronchi and bronchioles)?
4. If you increased the volume of the airways to match the resting tidal volume, would fresh air ever reach the alveoli?
5. Why does the tidal volume increase when the volunteer breathes through a tube?

Exercise 5: Breathing and Cardiac Function

Aim: To study changes in heart rate during breathing.

Equipment Setup

1. Untangle the plethysmograph cable.
2. Place the plethysmograph on the volar surface (where the fingerprints are located) of the distal segment of a middle finger; wrap the Velcro to attach the unit firmly to the end of the finger.
3. Push the DIN8 plug on the other end of the cable into the socket labeled channel one.

Procedure

1. The volunteer should sit quietly and, as before, should not be disturbed and should be relaxed and accustomed to breathing through the spirometer. The volunteer should try to breathe slowly and deeply.
2. Click Start and record breathing and the finger pulse.

Note: *The LabScribe software does a zero calibration during the first second of recording. No air should be moving through the flow head during this time.*

3. Click AutoScale in the channel one title area and see the rhythmic finger pulse signal get bigger.
4. Type deep breathing, ask the volunteer to breathe slowly and deeply, and press Enter on the keyboard; record about 10 complete breathing cycles.
5. Click Stop to halt recording.
6. Select Save in the File menu.

Data Analysis

Your data may look like Figure 4-20 on page 97.

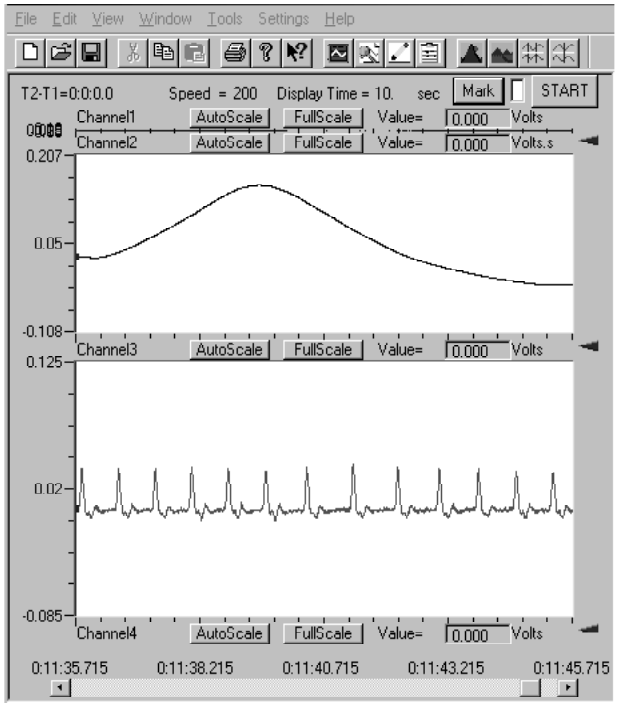

Figure 4-20: The integral of the spirometer signal (upper trace) and the finger pulse (lower trace) recorded and displayed in the Main window during slow, deep breathing.

1. Look at your data. Does the heart rate (as shown by the finger pulse) appear to change during the breathing cycle?
2. Quantify this by using the two cursors in the Analysis window to measure the time interval between peaks in the finger pulse record (Figure 4-20 on page 97). Make measurements during different phases of the breathing cycle.

Try the following experiments to further examine the link between breathing and heart rate:

¥ To examine the effects of gravity, repeat the deep breathing experiment with the subject lying on their back. Are the effects on heart rate as pronounced?

¥ Have the volunteer breathe out and then go through the motions to breathe in but close the mouth and nose i.e. lower the diaphragm and raise the ribs to inflate the thorax, but do not allow any air into the lungs. This will produce a negative pressure in the thoracic cavity. What is the effect on heart rate?

¥ Have the volunteer breathe in and then hold their breath as long as they can (this is the Valsalva maneuver) record breathing and finger pulse during apnea (hold breath) and during recovery.

Questions

1. Where is the heart in relation to the lungs?
2. If there is a negative pressure in the lungs, would the heart be subjected to the same pressure changes?
3. Would a negative pressure outside the capillaries functionally increase the transmural pressure i.e. the pressure difference between the inside of a blood vessel and the outside?
4. Would this create an increase in the blood pressure in the veins of the thorax i.e. those leading to the heart?
5. What would be the effect of a negative thoracic pressure on the rate of blood return to the heart?
6. What would be the effect of negative pressure on the heart rate? Do you see this?
7. Does gravity play a role in heart rate fluctuation during breathing?
8. How would a decline in blood O2 levels (and/or an increase in blood CO2 levels) influence heart rate as seen when the volunteer held their breath?

Appendices

The Transducers Included with the HK/256NI Human Physiology Teaching Kit

Your HK/256NI Human Physiology Teaching Kit is supplied with four transducers that enable you to perform the labs in the main section of the manual. Additional hardware, such as GSR-100 Galvanic Skin Response Meter and Force/Displacement Transducers, are also available. Detailed background on the transducers provided with your kit, as well as on the ETH-256 Combination Bridge/Bioamplifier is included in this Appendix. All of the transducers will connect directly into either the ETH-256 or the BNC connectors on channels one and two on the iWorx unit.

Included Items:

¥ Event Marker (Appendix A)

¥ Plethysmograph (Appendix B)

¥ Hand Dynamometer (Appendix C)

¥ Flow Spirometer (Appendix D)

¥ ETH-256 Combination Bridge/Bioamplifier (Appendix E)

Appendix A: The Event Marker

Figure A-1

The event marker is a simple electronic marking device. It connects to either of the 8 pin DIN Input Connectors on the ETH-256 Combination Bridge/Bioamplifier. Pressing the button on the top of the cylinder will send a +4V signal to the input of the channel to which the clicker is connected. Releasing the button will return the voltage to zero.

Appendix B: The Plethysmograph (pulse transducer)

To use the plethysmograph, simply connect it to either of the BNC fittings on the front panel of the ETH-256. The signal output of this transducer, when used to pick up your pulse, should be between 50 and 150 mV (this will vary for each individual, and with environmental conditions such as temperature). Adjust your gain accordingly. When attached to your thumb or forefinger with the supplied Velcro strap, it can be used to visualize a volume pulse waveform.

As its alternative name (pulse transducer) implies, the plethysmograph displays a representation of your pulse, but it is a generally useful accelerometer. The transducer is based on a piezoelectric crystal. Piezoelectric materials develop voltage while their shape is being changed. For example, if you place a weight on such a crystal, while the weight and the force of gravity are compressing the crystal, it gives off a voltage proportional to the acceleration of its outer edge away from the deforming force. When the final compressed state is reached, the outer edge of the crystal is no longer moving and no voltage is evident. It stays in this no output state until the weight is removed and the crystal expands. Again, voltage proportional to acceleration is produced, but this time the polarity of the voltage is the opposite of that produced during compression, since the acceleration is in the opposite direction.

Try this with your plethysmograph: while recording, gently squeeze it between your thumb and forefinger, hold it for a second and then release it. Note that the positive spike displayed in the window when you squeeze and the negative spike when you release.

Warning: *Squeezing too hard can collapse the transducer surface.*

The plethysmograph is an AC-coupled device. That means its output will always return to zero after the pressure event has been recorded. The AC nature of the plethysmograph means that you never need to adjust the zero position of the transducer, and that you can increase the gain of the recording amplifier as high as you like to

record even the smallest events. Conversely, you cannot measure steady state forces. The plethysmograph cannot be used as a force transducer.

Appendix C: The Hand Dynamometer

The hand dynamometer is an air-filled bulb with a pressure sensor sealed inside which connects to either of the 8-pin DIN Input Connectors on the ETH-256 Combination Bridge/Bioamplifier. As you grip the bulb, the pressure inside climbs, causing the sensor to put out more voltage.

Because a certain amount of pressure exists in the bulb when it is not being squeezed, the baseline will not be zero Volts. Most sensors will display a 60-70 millivolt offset.

Using the Hand Dynamometer

Plug the cable extending from the bulb into either of the 8-pin DIN Input Connectors on the ETH-256 Combination Bridge/Bioamplifier. Open the input amplifier for the channel to which you are connected and observe the voltage. Make sure that the 50Hz filter and both positive and negative check boxes are checked as in the diagram below.

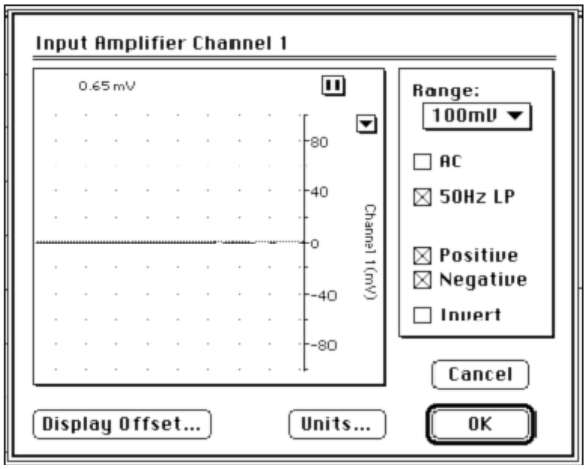

Figure A-2

The sensor will produce approximately 3mV per kilogram of applied force. In light of the offset and the output sensitivity, the scale should be set to about 200mV. Use the set scale option (in the unlabeled pull-down menu to the right of the Y-axis in the input amplifier window) to view only the 50-200mV area of the screen.

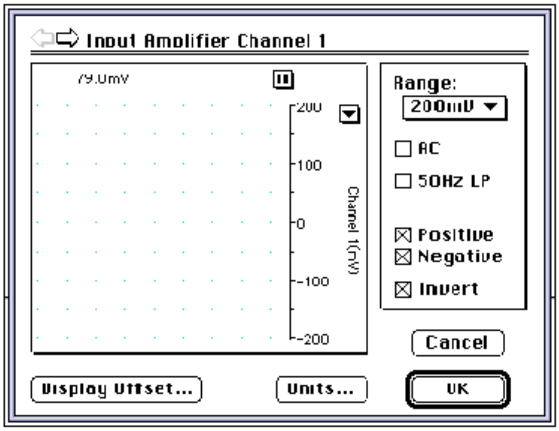

Figure A-3

If your transducer has a higher or lower baseline, you will need to set the scale accordingly (e.g., if your baseline is 80mV instead of 50mV, you should set the scale to display only the 80-20 mV region).

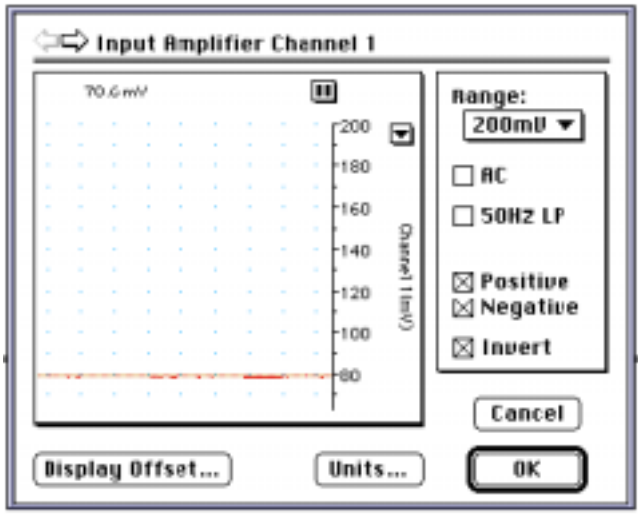

Figure A-4

You can use the units conversion option (the Units... button in the Input Amplifier window, or in the channel menu) to convert from millivolts to percent. For example, you could assign the baseline voltage of the dynamometer to 0%, and the voltage obtained when you grip it as hard as you can to 100%, as shown below.

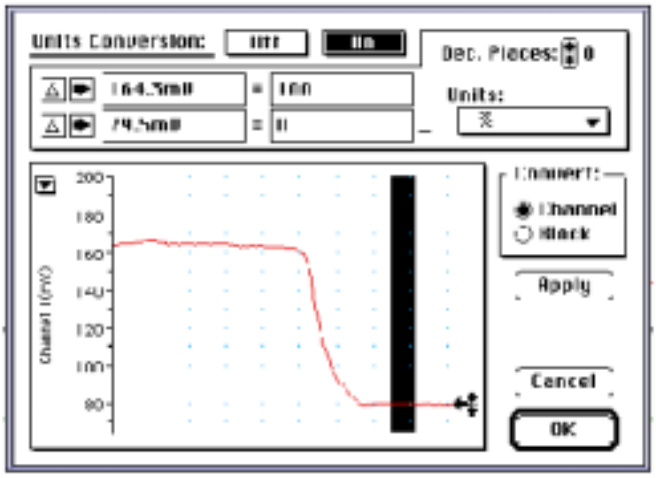

Figure A-5

Appendix D: The Flow Spirometer

The flow spirometer measures volumes and flows from normal breathing. To use the spirometer, connect it to either of the Input Connectors on the ETH-256 Combination Bridge/Bioamplifier.

What It Is

The Flow spirometer provided with the Human Physiology Teaching Kit consists of three parts:

1. An electronic sensor that functions as a handle
2. A disposable or reusable flowhead
3. Polyethylene tubing used to attach the flowhead to the sensor

How It Works

The spirometer box contains a differential air pressure sensor. It measures the difference in air pressure between the front and rear sides of the mesh screen in the flow head supplied in the kit. When the spirometer is assembled, blowing into the mouthpiece will produce a measurable pressure difference across the screen in the flowhead. The sensor will produce a voltage, which is directly proportional to the pressure. It is this voltage that the iWorx unit records.

Assembling the Flow Spirometer

Push the two plastic tubes onto the inlet ports of the sensor. A small amount of cotton can be placed in each tube to guard against condensation, but is not necessary. Press a flowhead onto the other end of the two plastic tubes.

Using the Flow Spirometer

Plug the spirometer cable into either of the inputs on the rear of the ETH-256. Open the input amplifier for the channel that you are connected to and observe the voltage. Press the red zero button on the back of the spirometer box. Adjust the output completely to zero using the zero offset knob on the front panel of the ETH-256.

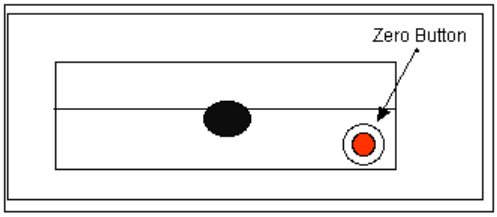

Figure A-6

Be sure to fix the spirometer box so that it cannot move around during the measurement. The internal differential sensor is measuring pressure in tenths of mm of water, any movement will produce an artifact that the iWorx unit will read as a volume. Secure the spirometer box by clamping it in a ring stand or taping it down to the lab bench. Be sure to allow about 7-10 minutes after you plug the spirometer in to warm up. If you blow into the mouthpiece you should see the trace move up or down. The value in Volts is directly proportional to flow in liters per minute.

How Do We Get Volumes?

If we know the flow rate and measure the time, we can calculate the volume. For example, if the flow rate is one liter per second and the flow continues for 10 seconds, the total volume is 10 liters. If the flow rate is constant we can do the volume calculation in our heads. But as you can see from testing the flowhead, the flow rates are constantly changing. You can obtain the volume if the computer calculates the area under the flow curve. In this operation, called integration, the computer continuously measures and reports the area between the flow line and zero. This is why it is important to have adjusted the zero correctly, as described above.

How Do We Get Correct Units?

When correctly adjusted, the spirometer will produce about 145mV per liter per minute of flow. This linear relationship will hold true up to about 250 liters per minute, which is fine for most non-exercise testing. Enter the data in the following figure into the Units Conversion dialog box as shown below. To get the display to read in liters per minute, use the Define Units item under the Units pull-down menu in the Units Conversion Dialog window, as shown below. You are now ready to proceed.

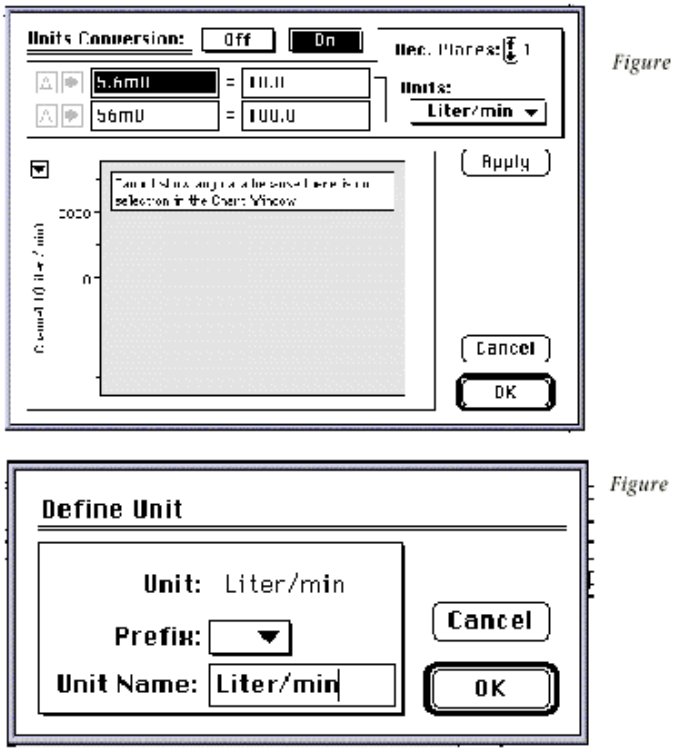

Figure A-7

Appendix E: The ETH-256 Combination Bridge/ Bioamplifier

Overview

The ETH-256 is a combination transducer and biopotential amplifier. Its controls, filter settings and gains were selected with these applications in mind, thereby making it well suited for the student physiology and the research lab. The ETH-256 is powered by a wall transformer (12 Volts AC 1000mA). It connects to the ETH-256 with a standard 3.0mm phono plug through a receptacle on the rear panel. The ETH-256 uses an optically isolated pod and patient cable for recording biopotentials (ECG, EMG,EEG) from human subjects.

Note: *Under no circumstances should human subjects be connected to the ETH-256 without employing this pod and cable.*

Using the biopotential pod and cable, the ETH-256 can allow display of any of the 12 ECG lead positions. You can change which leads are displayed by manually changing connectors.

Figure A-8

Topography

Front Panels and Controls

The ETH-256 is divided into two identical functional units (Figure A-8 on page 106), capable of making low noise AC coupled recordings of bioelectric potentials or DC coupled transducer recordings. Three push-buttons and one knob control each channel, the functions of which are described below. In addition, the input connectors for each channel can be found on the front panel.

High-Pass Filter

The high-pass filter has four positions. Each time the button is pushed it advances in step-wise fashion to the next position. The position DC couples the input and is used for measuring from weatstone bridge-style transducers or other ground-referenced sensors requiring impedance conversion, such as pH electrodes or Ion Selective Electrodes (ISEs). There are three high pass filter settings, 0.03, 0.3 and 3Hz, which are used for ECG, EEG and EMG, respectively. The higher the value of the AC coupling filter, the more signal contributions from body movement or breathing are removed and the more stable the baseline becomes.

Input Offset

The amplifier will output a baseline signal in either bridge (DC) or bio (0.03, 0.3 and 3Hz) mode. This signal level can be moved up (positively) or down (negatively) by using the input offset knob. This control is of greatest use in bridge mode where adjustments to zero the output of a transducer or maximize the use of the screen or paper display area are required.

Gain

Each channel of the ETH-256 has independently adjustable gain. This allows very small signals to be amplified before presentation to the display device. The gain control allows you to select among eight preset multipliers; x1, x5, x10, x50, x100, x500, x1k and x5K.

Low-Pass Filter (Hz)

The low-pass filter control sets the upper limit of frequencies measurable by the ETH-256. The 10K setting offers a maximum frequency response of about 10kHz. Other settings may be chosen to limit noise. For example, the 50Hz filter removes all signals above 50Hz. This, of course, includes powerline noise, the most common source of electrical interference. For very slow signals such as output from force or pressure transducers, the 5Hz setting will provide the quietest recording.

Input

The input connectors are either BNC for single-ended devices or DIN 8 for transducers, including the isolated biopotential recording pod.

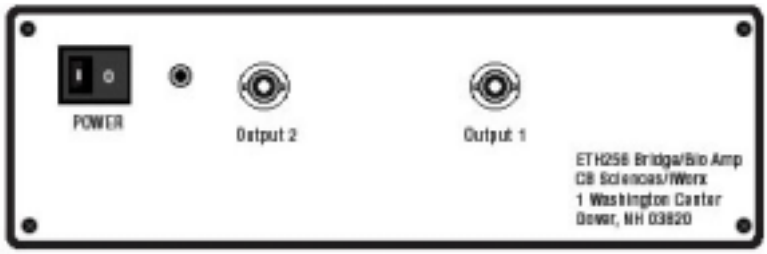

Figure A-9

Rear Panel and Connectors

The BNC output connectors for the ETH-256 are located on the rear panel. It can be cabled to your recorder or data analysis system using a common BNC-to-BNC cable. In addition to the output connectors the rear panel includes the power transformer input and the power switch.

Operation in Bridge Mode

Input

The ETH-256 input connector is a standard eight pin DIN type located on the rear panel of the device. This provides rapid and reliable connection of transducers to the amplifier. The DIN mating component is a male eight pin DIN available from Preh (p/n 71408). The wiring of this connector is illustrated in Figure A-10 on page 108. A list of wiring schemes for common transducer types is found in the Appendix.

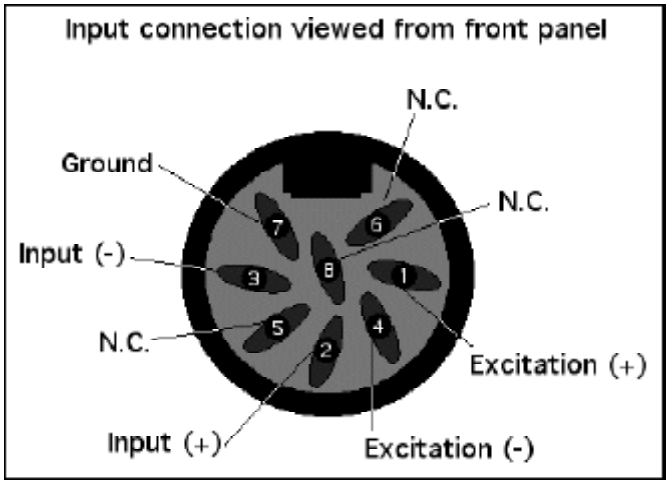

Figure A-10

Offset

To adjust transducer offset over the full input range, use the 10-turn potentiometers mounted on the front panel. This allows precise control of the baseline position while still allowing substantial transducer offsets to be nulled.

Operation

Transducers are connected to the input of the ETH-256 by means of a standard eight-pin DIN type connector. This connects the transducer to the –5V excitation, the positive and negative inputs of the differential amplifier and to the circuit ground.

Once the transducer has been correctly wired to the male eight-pin DIN connector, it is attached to an input channel on the ETH-256. The output of the transducer can now be viewed (at the selected gain) from the output BNC connector on the rear panel. Adjust offset as necessary.

Sample procedure for use of strain gauge type transducers with the ETH-256:

¥ After the transducer has been correctly fitted with an eight-pin DIN connector and attached to the appropriate input socket on the amplifier, connect the output BNC on the ETH-256 to the input of your recording device.

¥ Set the ETH-256 gain to x1 and the filter to 5Hz.

¥ Observe the output of the ETH-256 on your recording device. Confirm that the baseline position can be affected by turning the input offset knob for this channel. Adjust the baseline to zero Volts.

¥ If you cannot see the baseline move when you turn the input offset knob, try increasing the gain. A word about increasing gain it s possible that your recorder will also amplify and/or position a signal. To avoid confusion, use only one set of controls to adjust gain or offset once the signal is positioned.

¥ Continue to increase the gain until you can easily position the line with the input offset control. If you cannot see a signal on your recorder or if the signal is pegged all the way to the top or bottom of the recorder range, disconnect the transducer immediately and refer to the troubleshooting section of this manual.

¥ Now that you have your signal positioned, deflect your transducer by an amount appropriate to your experiment. For example, if you have connected a blood pressure transducer, apply approximately 250mmHg, or if you have connected a force transducer, hang a weight from it which is approximately equal to the maximum force you expect to see.

¥ Does the trace go off the screen or paper? If so, reduce the gain. If the deflection on the screen appears small (less than 20% of the full screen or paper), increase the gain. Your ETH/transducer is now ready to calibrate. Refer to the manual that came with your recorder for the best procedure to accomplish this.

Amplification with no excitation voltage:

The high input impedance of the ETH-256 in bridge mode makes it useful for transducer types other than resistive bridges. Piezo-electric, pH or any device with a signal output less than –5V can be applied to the inputs in differential and single ended modes. Be careful to shield the cable and source when using high impedance devices.

Sample procedure for use of a pH sensor with ETH-256:

¥ Set the ETH-256 gain switch to x1 and the filter setting to 50Hz. Put the electrode in pH 7.0 buffer. Observe the output of the ETH-256 on your recording device. Use the input offset to adjust the output to zero. Use a pH 10 buffer to do the second measurement. Select a gain on the ETH-256 that allows the deflection from zero produced by the change of buffer to be seen. Refer to the manual that came with your recorder for the best procedure to accomplish this.

Operation in Bio Mode

With either the 0.03, 0.3 or 3 Hz High Pass Filter LED illuminated, the amplifier is ready to record biopotentials. Any of these settings AC couples the input. AC coupling selectively removes the DC component of signals you are trying to record. For example, when

recording ECG, the surface electrodes provided will generate relatively small galvanic (steady state) potential between them when placed on the skin. This potential, while small, is many times the amplitude of the ECG signal you are attempting to record. In DC-coupled mode, gain applied to the ECG component of the signal must also be applied to the galvanic potential. In most cases a gain large enough to see the ECG in DC mode will saturate the amplifier.

AC coupling the input selectively removes the galvanic potential and leaves just the ECG. You can now use all the gain required. In addition to DC signals, the 0.03, 0.3 or 3Hz filters will remove slowly moving AC signals as well (artifact due to breathing or movement).

Control/Setup

Advance the high pass selection so that the 0.3Hz LED is illuminated and set the gain to x10. As with the bridge mode, it is a good idea to use only one set of controls to adjust the gain or offset. Select the 150Hz low pass filter if you are recording ECG or 1kHz if you are recording EMG.

Isolated Pod and Patient Cable

The ETH-256 comes with a 3-lead isolated pod and patient cable. This cable may be used on either input. The cable contains a x50 amplifier and an optically isolated output stage. When connected to the ETH-256, the gains set on the front panel are, therefore, multiplied by 50.

Connecting the Leads

Attach surface electrodes to the subject. These leads should have a snap connector to be used with the supplied cables.

Operation

With the settings above, you should now see the trace slowly approach zero. This can take 10 to 15 seconds if the amplifier has been open circuited for any length of time, so be patient and let the trace settle before you attempt to adjust offset. If the trace is noisy or wanders, see the troubleshooting section of this manual. Assuming the trace is stable and quiet, increase the gain until you can see an acceptable signal. When used with the isolated pod, a gain of x10 set on the front panel will produce an electrocardiogram of between .5 and 1 Volt.

The ETH-256 can be used to record signals such as ECG, EMG, EOG and EEG. It can also be used to measure from muscle and nerve directly. It is ideally suited for frog sciatic experiments or measurements in vivo with hook electrodes.

Sample procedure for recording ECG:

Plug the supplied isolated pod and cable into the input socket for channel one. Using an alcohol prep or alcohol soaked cotton ball, lightly abrade the skin on the underside of each forearm and on the back of the calf near the ankle. After the skin dries, attach a disposable, adhesive-backed electrode to each of the sites. Connect the brown lead (ground) to the leg. Connect the white lead (positive channel one) to the left arm and finally the green lead (negative channel one) to the right arm. The output now available on channel one is the ECG Lead 1." Increase the gain until the form of the ECG can be clearly seen. Other ECG lead configurations are given at the end of this chapter.

Sample procedure for recording EMG:

In this experiment, we will be recording an EMG signal from the anterior forearm muscles. Using a felt tip pen, mark the skin of your subject on the anterior forearm two-thirds of the distance from the wrist to the antecubital space (bend of the elbow). Then, have him/her flex his/her fingers tightly into a fist and mark a spot about two centimeters above the crease of the wrist where you see the appearance of tendons. Lastly, place a mark halfway and slightly off-line between the other two marks. Using an alcohol soaked cotton ball, lightly abrade the skin at each of these sites. After the arm dries, attach a disposable, adhesive-backed electrode to each of the sites. According to Figure A-11 on page 111, connect the leads from the ETH-256 biopotential pod to the forearm electrodes.

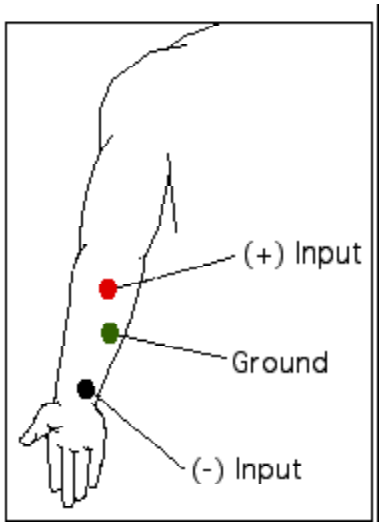

Figure A-11

Have your subject sit quietly in a chair with their forearm resting on a table with palm turned upward. With the subject's finger flexor muscles relaxed, begin recording the EMG signal. After approximately five seconds, have the subject contract the finger flexor muscles gently (make a fist) and hold for about two seconds, then relax again. Alternate periods of rest, with progressively stronger contractions until the subject contracts the flexor muscles maximally, then stop recording.

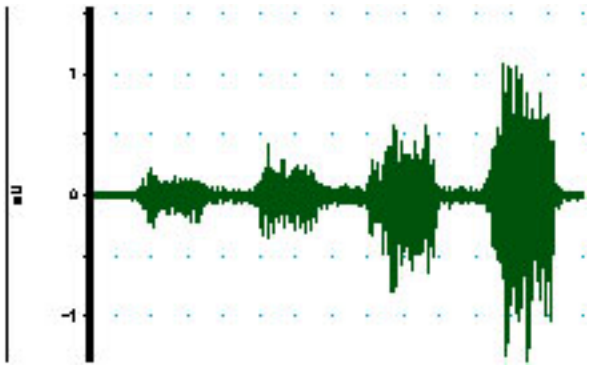

Figure A-12

Troubleshooting

¥ In DC mode, trace remains maxed to one side, offset has no effect. Check that the transducer is not overloaded and that the gain is not set too high the ETH-256 and your recorder may be accurate. If your transducer is not reacting to a large pressure or force, there are only two explanations for a large offset. The first is that one of the inputs to the differential amplifier on this channel is not connected. The second is that one of the power leads that supply the transducer may have shorted to the input or directly to ground. In either case, open the connector on the transducer and confirm that the wiring is correct and that there are no shorts.

¥ In the DC mode, when using the ETH-256 with data acquisition devices sampling at low speed, a slow sinusoidal drift appears. Sinusoidal drift observed when using digital recording devices is almost always due to aliasing of higher frequency noise. The most likely culprit in this case is the mains frequency. Use the 50Hz low-pass filter on the ETH-256 and any mains frequency or line filters that may be available on your recorder to minimize or remove this artifact.

¥ **When using a high pass filter other than DC, the signal is noisy and wanders.** Noise in the recording of biopotentials is frequently from the power lines in the room. Normally the differential properties of the amplifier can remove it, but this becomes difficult if the electrode connection to the subject is of high or variable resistance. Make sure that surface electrodes are securely fastened to the subject by gently abrading the skin surface where the electrode will be attached with some nylon scrubbing material. Be sure to use enough electrode gel if you have German silver (reusable) electrodes.

¥ **The offset works, you can see the trace, but there is no signal.** Make sure that you are using enough gain to see the changes produced by your transducer or by an ECG/EMG. Remember these signals can be just a few millivolts. If you use the 10V scale you won't see much.

¥ **Check the obvious:** Are the amplifier and recorder connected to a working outlet? Are you turning the switches and knobs on the correct channel? Are you sure about the connection to your recorder?

Specifications

Number of Channels:	2
Operational Modes:	Bridge/Biopotential(ECG, EMG,EEG)
Gain:	x1, x5, x10, x50, x100, x500, x1k, x5k
Filters:	High Pass (Hz): DC, 0.03, 0.3, 3.0
	Low Pass (Hz): 5.0, 50, 150, 2 k, 10 k
Power Source Wall	
Adapter:	12 VAC, 1 Amp
Ground Isolation:	Optical with C-ISO-256 isolated cable
Input Impedance:	10 GOhm
Output Impedance:	100 Ohm
Input Connectors:	DIN 8 or BNC
Output Connectors:	BNC
Offset Range:	–5V
Excitation Current:	50 mA per channel
Excitation Voltage:	–5V
	CMR 85dB up to 200 hz

Appendix F: Amplifier Tables

You'll probably find this table and legend helpful when choosing which iWorx products are suitable for your applications.

Table 1: Circulatory System

Physiological Parameters	Measurement Required	Sensing Devices Used	Typical Parameter Amplitude	Parameter Frequency (Hz)	Appropriate Amplifier	Accessories/ Sensors
Heart Potentials	Electrocardiogram	Surface Electrodes	2mV	0.05-80	ETH-256 PA-400	Surface Electrodes
		Heart Electrodes	50mV	0.05-80		
	Vector cardiogram	Surface Electrodes	2µV	0.05-80	ETH-256 PA-400	Surface Electrodes
	Fetal Electrocardiogram	Surface Electrodes (mother)	10µV	2-100	ETH-256 PA-400	Surface Electrodes
Blood Pressure	Direct Arterial Pressure at Brachial Artery	Pressure Transducer	120mmHg	DC-20	ETH-200 ETH-400 ETH-256	BP-100
	Direct Arterial Pressure at Femoral Artery	Mercury Manometer	120mmHg	DC-20	ETH-200 ETH-400 ETH-256	BP-100
	Direct Venous Pressure	Pressure Transducer	9mmHg	DC-20	ETH-200 ETH-400 ETH-256	BP-100
	Indirect Arterial Pressure	Sphygmomanometer	120/ 80mmHg		ETH-200 ETH-400 ETH-256	Cuff BP-100
		Korotkoff Microphone	150mV	30-500	ETH-256 PA-400	

Table 2: Respiratory System

Physiological Parameter	Measurement Required	Sensing Devices Used	Typical Parameter Amplitude	Parameter Frequency (Hz)	Appropriate Amplifier	Accessories/ Sensors
Breathing	Pneumogam	Thermistor Pneumograph	500cc/breath	0.05-2	ETH-200 ETH-400 ETH-256	

Table 2: Respiratory System

Physiological Parameter	Measurement Required	Sensing Devices Used	Typical Parameter Amplitude	Parameter Frequency (Hz)	Appropriate Amplifier	Accessories/ Sensors
Respiratory Flow	Pneumot-achogram	Pneumot-achograph w/Pressure Transducer	20,000cc/ mL	DC-2	ETH-200 ETH-400 ETH-256	SP-304 Flow Heads
Respiratory Volume	Spirogram	Spirometer	4,000cc	DC-0.5	ETH-200 ETH-400 ETH-256	SP-304 Flow Heads

Table 3: Brain Functions

Physiological Parameter	Measurement Required	Sensing Devices Used	Typical Parameter Amplitude	Parameter Frequency (Hz)	Appropriate Amplifier	Accessories/ Sensors
Electrical Activity	Electroenceph-alograph	Scalp Electrodes	50µV	0.5-100	ETH-256 PA-400	Electrocap Montage
		Intracranial Elec-trodes	500µV	0.5-100	ETH-256 PA-400	
Evoked Responses	Intracellular Potentials	Microelectrodes	100mV	1-10,000	ETH-256 PA-400	
	Extracellular Potentials	Needle Electrodes	50µV	1-1,000	ETH-256 PA-400	DHS-300
Eye Response	Electroretino-gram	Contact Lens Electrode	100µV	0.5-20	ETH-256 PA-400	

Table 4: Muscular Functions

Physiological Parameters	Measurement Required	Sensing Devices Used	Typical Parameter Amplitude	Parameter Frequency (Hz)	Appropriate Amplifier	Accessories/ Sensors
Muscle Strength	Myogram	Needle or Surface Electrodes	1mV	10-5,000	ETH-256 PA-400	Surface Electrodes
Muscle Potentials	Electromyo-gram	Needle or Surface Electrodes	1mV	10-5,000	ETH-256 PA-400	
		Electromyogram w/Needle or Sur-face Electrodes			ETH-256 PA-400	
Stimulation		Stimulate w/Sur-face Electrodes			ETH-256 PA-400	

Table 4: Muscular Functions

Physiological Parameters	Measurement Required	Sensing Devices Used	Typical Parameter Amplitude	Parameter Frequency (Hz)	Appropriate Amplifier	Accessories/ Sensors
Nerve Conduction	H Reflex Response	Electromyograph w/Reduced Stimulation			ETH-256 PA-400	
Conduction Velocity	Electromyo-graph			10-50,000	ETH-256 PA-400	NBC-200
Smooth Mus-cle Activity	Electrogastro-gram	Surface Electrodes	20mV	0.05-2	ETH-256 PA-400	
Organ Bath Studies		Force Transducer	5gms	DC-4	ETH-200 ETH-400 ETH-256	FT-100 FT-302

Table 5: Autonomic Nervous System

Physiological Parameters	Measurement Required	Sensing Devices Used	Typical Parameter Amplitude	Parameter Frequency (Hz)	Appropriate Amplifier	Accessories/ Sensors
Sweat Gland Activity	Galvanic Skin Response	Lead Surface Electrodes	50kOhms	DC-5	GSR-200	
	Electrical Skin Resistance	Lead Surface Electrodes	50kOhms	DC-5	GSR-200	
Body Temperature	Temperature	Thermistor Probe	98° F	DC-0.1	ETH-200 ETH-400 ETH-256	TM-100

Table 6: Oxygen Measurements

Physiological Parameters	Measurement Required	Sensing Devices Used	Typical Parameter Amplitude	Parameter Frequency (Hz)	Appropriate Amplifier	Accessories/ Sensors
Dissolved Oxy-gen		Clark Style Elec-trode	1-20nA	DC-1	ETOX-M	Oxygen Electrode