

Respiration

Background

The amount of air that moves in or out of the lungs during any one breathing cycle is called the **tidal volume**. Above and beyond 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 the **expiratory reserve volume**. Even if the expiratory reserve volume is fully expelled from the lungs, there is still a volume of air in the lungs, called the **residual volume**, which cannot be exhaled. The residual volume has low oxygen and high carbon dioxide concentrations. Upon inhalation, fresh air mixes with stale air from the residual volume to create air in the alveoli that still has gas concentrations that facilitate the diffusion of oxygen into and carbon dioxide out of the capillaries.

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 can be changed. The respiratory rate and the tidal volume are multiplied to calculate the **ventilation rate** (usually in L/min.)

Equipment Required

PC Computer
iWorx unit, and USB or serial cable
SP-304 Spirometer
FH-300 Spirometer flow head and plastic tubes
Needle and thread

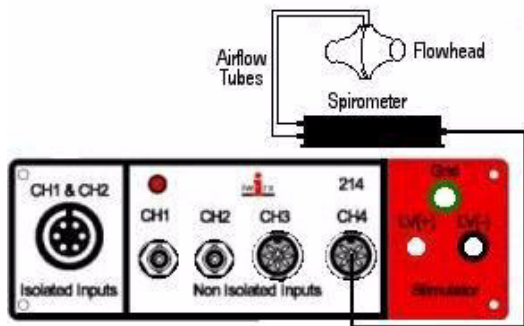


Figure 1: Connect the spirometer to the iWorx/214 unit.

Equipment Setup

- 1 Firmly push the two air flow tubes onto the two outlets on the flow head.
- 2 Firmly push the other ends of the two air flow tubes onto the two outlets on the SP-304 spirometer unit.
- 3 Plug the DIN connector of the spirometer into Channel 4 (Figure 1).

Start the Software

- 1 Click on the **Settings** menu and select the **Breathing-Rest-Exercise** settings file.
- 2 After a short time, LabScribe will appear on the computer screen as configured by the **Breathing-Rest-Exercise** settings.
- 3 Close the pdf file that opens automatically.

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 outlets on the flow head should always be in the upright position to avoid problems with condensation developing in the airflow tubes.
- 3 Turbulence in the flow head will produce a noisy signal. To reduce turbulence, the subject should place his or her lips around the outside of the opening of the flowhead, or its mouthpiece, or its bacterial filter.
- 4 Use a clip to prevent air from entering or leaving the nose as the subject is breathing. Air that passes through the nose is not included in the volume measurements and causes errors in these values.

5 The settings file, **Breathing-Rest-Exercise**, programmed LabScribe to display the **Airflow** of the spirometer on Channel 4, and the **Volume** on Channel 5. The settings file activates an algorithm designed specifically to convert the airflow data of the iWorx SP-304 spirometer to volume data.

6 **Right-click** on the **Volume** Channel (CH 5). Select **Spirometry** and be sure that the **Volume** option is checked. If it is not checked, select it now.

7 Allow the SP-304 to warm up for 10 minutes before recording for the first time. Do not hold the spirometer amplifier in your hand; the heat of your hand will alter the volumes recorded.

8 Determine which opening of the flowhead should be used to make the deflection on the **Airflow** channel (CH 4) go up as the subject inhales. (See directions in next step.)

9 Open the **Window** menu in the LabScribe software, and select **Preview**. A window displaying the signal coming into **Channel 1** of the iWorx unit appears. Click on the arrows above the display to change the channel being viewed in the display to the **Airflow** channel. Watch the display as the subject inhales. To increase the size of the trace, click **AutoScale**. The trace on the display should go up as the subject inhales. If the trace goes down during inhalation, breathe through the other end of the flowhead or reverse the airflow tubes on the outlets of the flowhead.

Exercise 1A: Breathing in Resting Volunteers

Aim: To measure breathing parameters in a resting individual.

Procedure

- 1 The subject should sit quietly and become accustomed to breathing through the spirometer. They should be breathing normally before any recordings are made. Remember to hold the flowhead so that the outlets are on top.
- 2 Have the subject remove the flowhead from his/her mouth. They should hold it at the same level as their mouth, but in a position that prevents his/her breath or any other airflow from moving through the flowhead.

Note: The LabScribe software will zero the **Volume** channel during the first five seconds of recording. No air should be moving through the flow head during this time.

3 Click **Start**. Type "Resting" in the comment line to the right of the **Mark** button. After waiting five seconds for the **Volume** channel to zero, have the subject place the flowhead in their mouth and begin breathing. Press the **Enter** key on the keyboard. Click the **AutoScale** buttons for the **Air Flow** (CH 4) and **Volume** (CH 5) channels. Notice the slowly moving wave on the **Volume** channel. Record 5 breaths, which normally takes about 30 seconds. During this time, the **Volume** channel may automatically reset itself to zero; which it will do every 30 seconds after the recording begins.

4 Type "Maximum" on the comment line. Press the **Enter** key on the keyboard as the subject inhales as much as possible. As quickly as possible after reaching their maximum inhalation volume, the subject should exhale as quickly and as completely as possible.

5 The volunteer should return to normal breathing through the spirometer.

6 Click **Stop** to halt recording.

7 Select **Save As** in the **File** menu, type a name for the file. Choose a destination on the computer in which to save the file (e.g. the **iWorx** or class folder). Click the **Save** button to save the file (as an ***.iwd** file).

8 Now measure breathing parameters in all the other students in the lab group. Use a clean flowhead (or a new bacterial filter on the flowhead) for each new subject. Wash the flowhead in 5% bleach solution and rinse it 5 or 6 times with deionized water. Dry it with a blow dryer. Be careful not to touch the membrane inside of the flow head.

9 Open a new file for each new subject and repeat Exercise #1. Label each segment of file with appropriate comments.

10 Once the relevant parameters are calculated for each student (see below), fill in the class data table provided in the lab.

Data Analysis-Normal Breathing

1 Scroll the data until the beginning of the first breathing cycle appears on the **Main** window. Adjust the **Display Time** (Figure 2) so that two complete breathing cycles appear on the window.

2 Click the **2-Cursor** icon (Figure 2), so that two blue vertical lines appear over the recording window.

3 Drag the blue cursor lines left and right so that the two complete breathing cycles are located between the two blue lines.

4 Click the **Analysis** icon (Figure 2) to open the window.

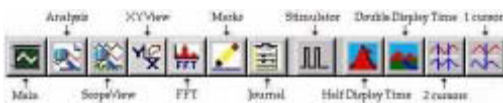


Figure 2: The LabScribe toolbar.

5 Display only the **Volume** (CH 5) by clicking and deselecting all the other channels in the **Display Channel** list, on the left side of the **Analysis** window. Select **Title**, **V2-V1**, **T2-T1**, **max_dv/dt**, and **min_dv/dt** from the **Table Functions** list.

6 Use the mouse to click and drag the cursors over each of the five breathing cycles to measure the following parameters:

- **Tidal Volume (TV)**: the amplitude of the breathing cycle. Place the one cursor in the trough prior to the inhalation, and the second cursor to the peak of the cycle. The value, **V2-V1**, is the Tidal Volume (Figure 3).

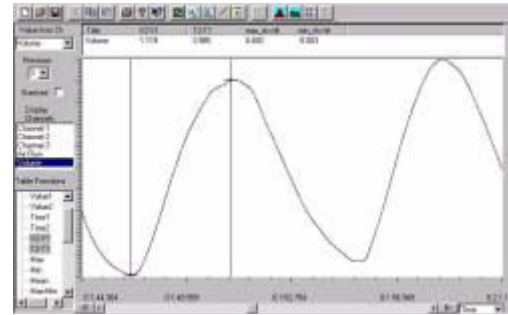


Figure 3: The Volume displayed in the Analysis window; an upward deflection represents inspiration. The cursors are positioned on the trough and the peak of the signal to measure the tidal volume (V2-V1).

- **Period**: the duration of each breathing cycle. The duration is easiest to measure between peaks or troughs on the **Volume** record. The value, **T2-T1** is the Period (Figure 4).

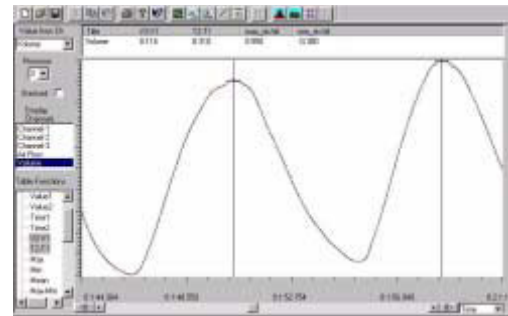


Figure 4: The Volume displayed in the Analysis window; an upward deflection represents inspiration. The cursors are positioned on the peaks of successive signals to measure the time interval (T2-T1).

- **Maximum Inspiratory Flow**: the maximum rate of air movement during inhalation. Place the cursors on either side of the steepest portion of the volume curve recorded during inhalation. The value, **max dv/dt**, is the Maximum Inspiratory Flow rate (Figure 5).

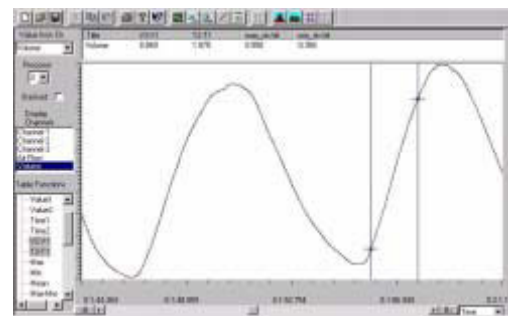


Figure 5: The Volume displayed in the Analysis window. The cursors are positioned on the steepest part of the inhalation slope.

- **Maximum Expiratory Flow**: the maximum rate of air movement during exhalation. Place the cursors on either side of the steepest portion of the volume curve recorded during exhalation. The value, **min dv/dt**, is the Maximum Expiratory

Flow rate. **Min dv/dt** is used since the exhalation curve has a downward or negative slope.

7 These data, along with the rest of the data for this lab, can be noted on the table on the last page of your handout.

Data Analysis-Maximum Breathing

1 Scroll the data in the **Analysis** window until the “Maximum” breathing cycle appears in the window. Adjust the **Display Time** (Figure 2) so the complete cycle appears on the window, from the normal tidal volume (or baseline) before the maximum inhalation to the flat line after the subject has completely expelled all the air from their lungs. Your data may look something like Figure 6.

2 Click the **2-Cursor** icon (Figure 2), so that two blue vertical lines appear over the **Analysis** window. Select **Title, V2-V1, T2-T1, max_dv/dt,** and **min_dv/dt** from the **Table Functions** list.

3 Drag the blue cursor lines left and right to measure; **Tidal Volume (TV), Inspiratory Reserve (IR), Expiratory Reserve (ER),** and the **Vital Capacity (VC)** (Figure 6). Also, measure **maximum rates for inspiratory and expiratory flows.**

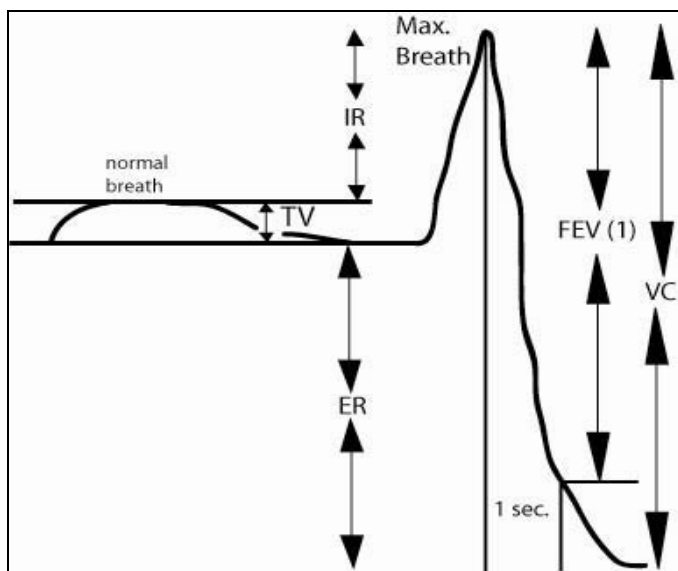


Figure 6: Volume displayed in the Analysis window; an upward deflection represents inspiration. The trace shows a normal breathing cycle (left) and then a forced inspiration and expiration (right); labels show tidal volume (TV), inspiratory reserve volume (IR), expiratory reserve volume (ER), vital capacity (VC), and Forced Expiratory Volume at 1 Second (FEV(1)).

4 Place a cursor on the point in the maximum volume trace where the maximum inspiratory volume is reached. Use the **T2-T1** function to place the second cursor at a point that is one second after the position of the first cursor. The **V2-V1** value for these two cursors equals the Forced Expiratory Volume at 1 Second or FEV(1).

Calculations

1 Use the mean duration of the breathing cycles to measure breathing rate:
Breathing Rate (Breaths/minute) = 60 seconds/minute
mean duration (secs)/breath

2 Multiply the mean tidal volume by the breathing rate to calculate the volume of air passing in and out of the resting subject's lungs each minute.

3 Determine the ratio of FEV(1) to VC. Normally, FEV(1) is compared to the Forced Ventilatory Capacity (FVC) which equals the Predicted Vital Capacity; but, for our purposes, we will use the actual Vital Capacity (VC). FEV(1)/FVC is an indicator of the severity of pulmonary impairment due to obstructions; any value greater than 65% is considered normal.

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 gender, smoking or apparent fitness?

1B: Breathing Immediately After Exercise

Aim: To measure breathing parameters after exercise.

Procedure

1 For this exercise, use just one subject. Attach a clean flowhead to the spirometer.

2 The volunteer should exercise to sufficiently 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 after concluding exercise. Click **Start**. Type “After Exercise” on the comment line to the right of the **Mark** button.

4 After waiting five seconds for the **Volume** channel to zero, have the subject place the flowhead in their mouth and begin breathing. Press the **Enter** key on the keyboard. Record five complete breathing cycles. Click the **AutoScale** buttons for the **Air Flow** (CH 4) and **Volume** (CH 5) channels.

5 Type “Maximum” on the comment line. Press the **Enter** key on the keyboard as the subject inhales as much as possible. As quickly as possible after reaching their maximum inhalation volume, the subject should exhale as quickly and as completely as possible.

6 Click **Stop** to halt recording.

7 Select **Save As** in the **File** menu, type a name for the file. Choose a destination on the computer in which to save the file (e.g. the **iWorx** or class folder). Click the **Save** button to save the file (as an *.iwd file).

Data Analysis

Measure the subject's breathing parameters immediately after exercise using the same techniques used in Exercises 1 and 2. Add this data to the table in the back of your handout.

Questions

1 Did tidal volume change after exercise? Did inspiratory and expiratory reserves change after exercise?

2 Did exercise influence the time taken for each breathing cycle?

3 Did the rate of air flow during the inhalation phase increase with exercise? How can you account for this?

4 Did the rate of air flow during the exhalation 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?

EXERCISE 2: FACTORS THAT AFFECT BREATHING PATTERNS

Background

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 (L/min.) can be influenced by many factors, including emotion, speech, disease and the body's position relative to gravity

Before Starting

1 The settings file, **Breathing-Other Factors**, programmed LabScribe to display the **Pulse** on channel 3, the **Airflow** of the spirometer on Channel 4, and the **Volume** on Channel 5. The settings file activates an algorithm designed specifically to convert the airflow data of the iWorx SP-304 spirometer to volume data.

2 **Right-click** on the **Volume** Channel (CH 5). Select **Spirometry** and be sure that the **Volume** option is checked. If it is not checked, select it now.

2A: Coughing

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

Procedure

1 The subject should sit quietly and become accustomed to breathing through the spirometer. They should be breathing normally before any recordings are made. Remember to hold the flowhead so that the outlets are on top.

2 Have the subject remove the flowhead from their mouth. They should hold it at the same level as their mouth, but in a position that prevents their breath or any other airflow from moving through the flowhead.

Note: The LabScribe software will zero the **Volume** channel during the first five seconds of recording. No air should be moving through the flow head during this time.

3 Click **Start**. Type "Resting" in the comment line to the right of the **Mark** button. After waiting five seconds for the **Volume** channel to zero, have the subject place the flowhead in their mouth and begin breathing. Press the

Enter key on the keyboard. Click the **AutoScale** buttons for the **Air Flow** (CH 4) and **Volume** (CH 5) channels. Notice the slowly moving wave on the **Volume** channel. Record 5 breaths, which normally takes about 30 seconds. During this time, the **Volume** channel may automatically reset itself to zero; which it will do every 30 seconds after the recording begins.

4 Type "Cough" on the comment line. Press the **Enter** key on the keyboard as the subject coughs.

5 The volunteer should return to normal breathing through the spirometer.

6 Click **Stop** to halt recording.

7 Select **Save As** in the **File** menu, type a name for the file. Choose a destination on the computer in which to save the file (e.g. the **iWorx** or class folder). Click the **Save** button to save the file (as an *.iwd file).

Data Analysis - Measurements

1 Scroll the data until the beginning of the first breathing cycle appears on the **Main** window. Adjust the **Display Time** (Figure 7) so that two complete breathing cycles appear on the window.



Figure 7: The LabScribe toolbar.

2 Click the **2-Cursor** icon (Figure 7-15 on page 161), so that two blue vertical lines appear over the recording window.

3 Drag the blue cursor lines left and right so that the two complete breathing cycles are located between the two blue lines.

4 Click the **Analysis** icon (Figure 7) to open the **Analysis** window.

5 Display only the **Volume** (CH 5) by clicking and deselecting all the other channels in **Display Channel** list, on the left side of the **Analysis** window. Select **Title**, **V2-V1**, **max_dv/dt**, and **min_dv/dt** from the **Table Functions** list.

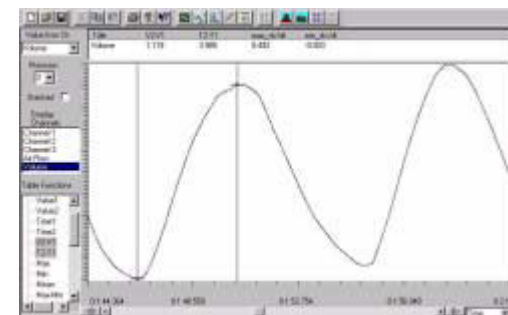


Figure 8: The Volume displayed in the Analysis window; an upward deflection represents inspiration. The cursors are positioned on the trough and the peak of the signal to measure the tidal volume (V2-V1).

6 Use the mouse to click and drag the cursors over each of the five breathing cycles to measure the following parameters:

- Tidal Volume (TV): the amplitude of breathing cycle. Place the one cursor in the trough prior to the inhalation, and the

second cursor to the peak of the cycle. The value, $V_2 - V_1$, is the Tidal Volume (Figure 7-16 on page 161).

- **Maximum Inspiratory Flow:** the maximum rate of air movement during inhalation. Place the cursors on either side of the steepest portion of the volume curve recorded during inhalation. The value, $\max dv/dt$, is the Maximum Inspiratory Flow rate (Figure 9).

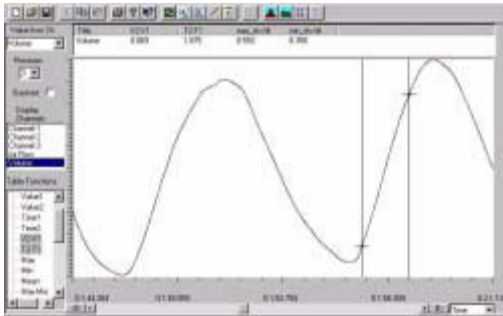


Figure 9: The Volume displayed in the Analysis window. The cursors are positioned on the steepest part of the inhalation slope.

- **Maximum Expiratory Flow:** the maximum rate of air movement during exhalation. Place the cursors on either side of the steepest portion of the volume curve recorded during exhalation. The value, $\min dv/dt$, is the Maximum Expiratory Flow rate. $\min dv/dt$ is used since the exhalation curve has a downward or negative slope.

7 These data can be entered into the **Journal** by either typing the titles and values directly or by using the **right-click** menu. Place the cursors to take measurements; then, select **Add Title to Journal** or **Add Data to Journal** from the **right-click** menu to add the measurements to the **Journal**.

8 Average the five values obtained for each parameter and enter them in a table in the **Journal**.

9 Determine the maximum airflow during the cough.

Questions

1 What phase of the breathing cycle (exhalation or inhalation) 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 exhalation and the cough. Which is faster?

2B: 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 subject, on the bench top or the top of the computer monitor.

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

3 Have the subject remove the flowhead from their mouth. They should hold it at the same level as their mouth, but in a position that prevents their breath or any other airflow from moving through the flowhead.

Note: The LabScribe software will zero the **Volume** channel during the first five seconds of recording. No air should be moving through the flow head during this time.

4 Click **Start**. Type "Resting" in the comment line to the right of the **Mark** button. After waiting five seconds for the **Volume** channel to zero, have the subject place the flowhead in their mouth and begin breathing. Press the **Enter** key on the keyboard. Click the **AutoScale** buttons for the **Air Flow** (CH 4) and **Volume** (CH 5) channels. During this time, the **Volume** channel may automatically reset itself to zero; which it will do every 30 seconds after the recording begins.

5 Type "Concentration" on the comment line. After the five normal breathing cycles, ask the volunteer to try to thread the needle. Press the **Enter** key on the keyboard as the subject begins their attempt.

6 Type "Through" and press the **Enter** key on the keyboard when the needle has been threaded

7 Click **Stop** to halt recording.

8 Select **Save** in the **File** menu.

Data Analysis

1 Just as it was done in Exercise 1, determine the average Tidal Volume, Maximum Inspiratory Flow, and Maximum Expiratory Flow from the **Volume** channel (CH 5) before, during and after the threading the needle.

2 Also, use the **T2-T1** function from the list in the **Analysis** window to measure the Breath Duration for 5 adjacent cycles in each of the three experimental conditions (Figure 10).

3 Enter your data into the **Journal** and construct a table that enables a comparison of the four breathing parameters during each of the three conditions of the exercise.

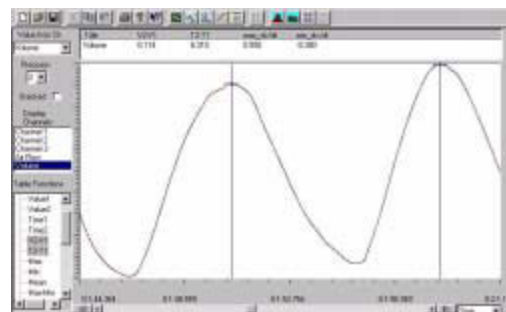


Figure 10: The Volume displayed in the Analysis window; an upward deflection represents inspiration. The cursors are positioned on the peaks of successive signals to measure the time interval ($T_2 - T_1$).

Questions

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

2 Can you explain your observations?

2B: Breathing after Hyperventilation

Aim: To compare breathing before and after hyperventilation.

Procedure

1 In the same manner used above, make a continuous recording of breathing that will include 1 minute of normal breathing, one minute of hyperventilation (breathing deeply and at the normal respiration rate) and one minute of normal breathing after the hyperventilation.

2 Determine the breathing rate, the tidal volume, and the ventilation rate both before and after the hyperventilation. Is there a hypoventilation to compensate for the prior hyperventilation, to allow blood gas levels to return to normal?

2C: Breathing after Re-Breathing in a bag

Aim: To compare breathing before and after re-breathing, when carbon dioxide levels are increasing and oxygen concentrations are decreasing in the bag, and in the body.

Procedure

1 Using the same methods as above, make a continuous recording of normal breathing for two minutes while breathing in/out of the bag. Make sure that the bag is held tightly over the nose and mouth.

2 Calculate and compare the respiratory rates, tidal volumes, and ventilation rates during the first and last 15 seconds of the period.

EXERCISE 3: BREATH-HOLDING COMPARISONS

Aim: To determine how prior breathing patterns, which will alter the normal blood oxygen and carbon dioxide concentrations, may affect the ability to hold one's breath.

Equipment Setup

All you need is a paper/plastic bag, and a visible clock with a second hand.

Procedure

1 Each student should take a single deep breath and hold it as long as possible, timing this breath-holding period.

2 After recovery from this, repeat the process, but first breathe the same air in/out of the bag for two minutes. Take the deep breath just prior to breath-holding from the bag too. Make sure to hold the bag over the nose and mouth, so that no new air is introduced.

3 Finally, after breathing has returned to normal, the subject will take ten deep breaths at about the normal respiration rate and hold the 10th inhalation as long as possible.

4 For all three of these breath-holding episodes, take care to inhale the same amount each time.

5 Record and compare the breath-holding ability within an individual.

	Lab Partner Name				After Exercise	Coughing	Concentration	After Hyper-ventilating	After Rebreathing
Normal									
TV (V2-V1)									
Period (V2-V1)									
Breathing Rate (Breaths/ min)									
Ventilation Rate (vol/min)									
Max Insp. Flow (max dv/dt)									
Max Exp. Flow (min dv/dt)									
Max Breath									
IR									
ER									
VC									
FEV1									
Max Ins									
Max Exp									
Breath Holding									
Normal									
After Hyperventilation									
After Hypoventilation									