Biology 13A Lab #12: The Respiratory System

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Expected Learning Outcomes
At the end of this lab, you will be able to
• locate the major gross structures of the respiratory system on the human torso model;
• use a computer and physiological data collection device to monitor the respiratory rate of an individual;
• determine the effect of increased carbon dioxide on breathing rate and depth; and
• explore the physiological effects of high altitude.

Figure 12.1. Lungs
The organs of the respiratory system include the nose, nasal cavity, sinuses, pharynx, larynx, trachea, respiratory tree, and lungs. They function to transport air to the air sacs of the lungs (the alveoli) where gas exchange occurs. The process of transporting and exchanging gases between the atmosphere and the body cells is respiration. The process of taking in air is known as inspiration, while the process of blowing out air is called expiration. A respiratory cycle consists of one inspiration and one expiration.

The point of respiration is to allow you to obtain oxygen, eliminate carbon dioxide, and regulate the blood’s pH level. Respiration rate (breaths per minute) and depth (volume of air inhaled and exhaled with each breath) varies due to changes in blood chemistry that are monitored by the brain. For example, when you exercise, demand for oxygen increases because the cells require more ATP. In turn, more carbon dioxide is produced by cells and diffuses to the blood. The rise in carbon dioxide leads to a decrease in pH, causing the blood to be more acidic. The brain is especially sensitive to pH levels; as pH levels in the blood fall, the brain stimulates more rapid breathing and deeper breathing. The effect is to draw more air into the lungs, to transport more oxygen to the cells, and to lower pH and CO₂ levels.

Check Your Understanding: Answer the following questions based on your reading of the introduction.

1. Where does gas exchange occur?

2. What is one complete respiratory cycle? Define breathing rate and breathing depth.

3. What happens to breathing rate and depth during exercise? What are the changes in blood chemistry that lead to the observed changes during exercise?
Activity 1: Structures of the Respiratory System

Using your text as a reference, locate the following structures on the model of the human torso and the real skull.

- Nostrils (external nares)
- Nasal cavity
- Nasal septum
- Nasal conchae
- Nasal sinuses
- Pharynx
- Larynx
- Vocal Cords
- Thyroid Cartilage (Adam’s Apple)
- Epiglottis
- Trachea
- Bronchi
- Lung
- Lobes of lungs
- Visceral Pleura
- Parietal Pleura

1. Breathing can also be called ________________.

2. When the diaphragm contracts, the size of the thoracic cavity ________________.

Activity 2: Measuring Respiration

The rate at which your body performs a respiratory cycle is dependent upon levels of oxygen and carbon dioxide in your blood.

You will monitor the respiratory patterns of one member of your group under different conditions. Each respiratory cycle will be recorded by the computer, allowing you to calculate a respiratory rate for comparison under different conditions.
**Equipment**

1. Airflow transducer (SS11A). The transducer for today’s lab is an airflow transducer. You will breathe into this apparatus and the software will convert airflow to volume. In order for this measurement to be accurate you must follow the procedure exactly as described.

2. Bacteriological Filter. This is a sanitary device designed to prevent contamination from user to user. This piece is NOT to be shared.

3. Disposable Mouthpiece. Obtain one of these from your instructor. This is the only part that your mouth will come in contact with during the exercise. This piece is NOT to be shared.

4. Nose Clip. The nose clip will prevent you breathing through your nose insuring that the airflow comes only from your mouth.

5. Calibration syringe. The syringe is for calibrating the Biopac unit, by delivering one full liter of air during calibration procedure. This will “teach” the software how much airflow corresponds to 1 liter.
Bio13A Lab Manual

**Starting Up**

1. Turn your computer ON. When the computer has finished booting up, turn the MP35 unit ON. The "Busy" light on the Biopac unit will flash. Once the "Busy" light goes out, launch the Biopac Student Lab software.

2. Choose Lesson 13 (**L13-LUNG-2**).

3. Type in your file name. Click **OK**.

4. Check to see if the airflow transducer (SS11LA) is plugged into Channel 1.

5. Place the calibration filter onto the end of the calibration syringe. NOTE: do not use your personal filter. Use the filter labeled "Calibration". A filter must be included in the calibration procedure because of the way it affects airflow. See Fig. 12.2.

![Figure 12.2. Calibration syringe with filter attached.](image)

6. Please read ALL of Step 6 before attaching the syringe to the airflow transducer. Insert the calibration syringe with its filter into the Airflow Transducer on the side labeled **Inlet**. **CAUTION**: The calibration syringes are extremely fragile. **NEVER HOLD ONTO THE AIRFLOW TRANSDUCER HANDLE** when using the calibration syringe or the tip will break off (See Fig 12.3a and 12.3b for proper handling). BOTH hands must be placed on the syringe itself. One hand should be on the plunger, the other on the body of the syringe (see Fig 12.3b).

![Figure 12.3a. Incorrect way to hold onto the syringe/transducer assembly.](image)
Calibration
You are not holding on to the airflow transducer handle now are you? Good. You should have both hands on the calibration syringe. Practice using the plunger of the calibration syringe until you feel you can get a smooth but firm motion of air moving in and out of the barrel. Continue once you feel confident with the handling of the syringe.

1. Pull the Calibration Syringe Plunger all the way out and hold the Calibration Syringe/Filter Assembly parallel to the ground.

2. Read the Journal window on the lower screen for directions:
   The first part of the calibration sets the baseline. It calibrates with no air movement within the barrel. Hold the syringe still without touching the plunger.
   Click Calibrate. A prompt will remind you to do nothing during this first part of calibration (Figure 12.4).

3. The second part of the calibration measures 1 Liter of airflow through the barrel. The method of delivery needs to be very precise and is described in detail in the Journal window on the lower screen of your computer. Read those directions before clicking Yes.
The following directions summarize the directions in the Journal window:
You will push and pull the plunger a total of ten times, 5 in and 5 out, forcefully enough to cause the plunger to produce a whistling sound. Practice this a few times before actually calibrating.

Follow this rhythm as you practice: plunger in, **wait 2 seconds**; plunger out, **wait 2 seconds**. Continue this pattern until you have finished the 10 strokes.

Note: The repeated strokes are required because of the complexity of the Airflow to Volume calculation. The accuracy of this conversion is increased when analyzing the airflow variations occurring over five complete cycles of the calibration syringe. When you are ready to begin, click **Yes**.

4. The second stage of the calibration procedure will begin to record. Wait 2 seconds, then begin by pushing the plunger in. Cycle the syringe plunger in and out completely 5 times (10 strokes) following the rhythm practiced above. Click **End Calibration**. Your calibration recording should look like Figure 12.5.

![Figure 12.5. Results from a correct calibration](image)

5. If your data looks like that of Figure 12.5, you can proceed to the next step. If it does NOT look like the image above, click **Redo Calibration**. It may take two or three tries to get the calibration right. Check with your instructor to determine what you may be doing wrong and repeat the calibration.

6. When you are satisfied with your recording gently detach the transducer from the calibration syringe and filter. **Be gentle**, as the torque on the syringe tip can cause it to break off.
**Recording Tidal Volume**

1. **Tidal Volume (TV)**, or respiration depth, is the volume of air that is inhaled or exhaled with each breathing cycle. It varies with conditions (e.g. rest, exercise, and posture). A more accurate measure is achieved if several breaths are averaged. Attach the subject's own filter onto the airflow transducer on the inlet side and then attach the mouthpiece onto the filter (Fig. 12.6).

![Airflow transducer with filter and mouthpiece attached.](image)

2. Seat the subject facing away from the computer monitor. The subject should wear the nose clip, and hold the airflow transducer by the handle (now you are allowed), with its attached filter and mouthpiece parallel to the floor. Keep the airflow transducer upright at all times (Figure 12.6).

**Practice Run**

3. Practice the first breathing routine without recording on the computer:
   
   Have the subject breathe in and out through the mouthpiece as normally and as relaxed as possible (easier said than done).
   
   It is OK to bite on the mouthpiece as he or she breathes. A breath is made up of one inhale and one exhale cycle. The subject should try to inhale normally, followed by an **unrushed** exhaling. There is a tendency to not exhale completely before beginning a new breath because of the awkwardness of the situation. Try to breath as normally as possible without too much conscious thought.

These steps differ from the prompt in the lower journal window on your laptop. Do NOT follow the computer screen prompt. Follow the directions on this handout instead. From here on, this handout will differ from the prompts on the screen. **Ignore the prompts.**
**Ready to Record - Part I Holding of Breath**

4. When ready and clear on the directions above, a member of the group other than the subject will click **Record FEV**.

5. Read the following steps aloud to your subject as you record.
   a) “Breathe normally until we tell you otherwise.” (Helper monitors recording for 60 seconds.)
   b) At the 60 second mark, have subject hold his or her breath for 30 to 45 seconds.
   c) When the subject releases his or her breath: “Breathe normally until we tell you to stop.” (Helper monitors recording for another 30 seconds.)

6. Click **Stop**.

7. You will collect data from this screen. **DO NOT click "Setup FEV"**.

---

**Measuring Tidal Volume**

1. Set up two measurement boxes on the upper left side of the screen (see Figure 12.8.). The first should be P-P, the second should be Delta T. P-P will measure volume in liters (Y-axis) and Delta T will measure time in seconds (X-axis).

![Figure 12.8. Measurement boxes set up for P-P and Delta T](image)

2. Choose one respiratory cycle (breath) before the subject’s breath was held. Measure the volume (Y-axis) of one breath (TV) by using the I-beam cursor to highlight the inhalation phase of one breathing cycle. Position the I-beam cursor from the valley to the peak of one breath (see Figure 12.9). Use three significant digits. Record **P-P** in liters in Table 12.1.
3. Measure the time of the same breath (cycle time) by positioning the I-beam from valley to valley. Record **Delta T** in seconds.

   Repeat these measurements for two more breathing cycles (before holding breath) from your recording. (Pick those without any major anomalies).

4. Calculate the average TV for all three cycles by adding together your three TV measurements and dividing by 3. Calculate the average cycle time by adding together the three cycle time measurements and dividing by 3. Record your results in Table 12.1. (Tidal volume values may range from 0.2 L to 0.6 L, depending on the size and respiratory health of the individual. Cycle time may range from 3 to 6 seconds per breath.)

   Note: Averages are preferable because they account for variability between breathes.

5. Repeat steps 2, 3 and 4 on cycles after holding breath. Record your results in Table 12.1.

6. **Do not exit your screen yet.** We will use the same file to collect one more set of data to observe how increased carbon dioxide affects breathing cycles.

**Calculating Respiratory Rate**

1. Calculate your subject’s Respiratory Rate before and after holding breath: **Respiratory Rate** (breaths/min) is the number of breaths in a minute. Use the average cycle time from Table 1 to calculate respiratory rate using the formula below.

   \[
   \text{Respiratory Rate} = \frac{\text{Number of breaths}}{\text{Cycle Time (sec)}} \times \frac{60 \text{ sec.}}{1 \text{ min.}}
   \]

   Average Respiratory Rate is between 12 and 17 breaths per minute. Record your results in Table 12.1.
Questions

1. Draw a sketch of your recording before and after holding breath. Label the X-axis “Time in seconds” and the Y axis “Volume in liters”.

2. Did the respiratory rate of the test subject change after holding his or her breath? If so, describe how it changed.

3. Define tidal volume.

4. Did the tidal volume of the test subject change following the release of his or her breath? If so, how did it change and why?

Ready to Record - Part II Rebreathing of Air

1. We are still using the old screen. Make sure you have recorded all the values in the last exercise because your old screen will now be erased. Click Redo and erase the current FEV data.

2. Click Yes. You are actually performing a new experiment, but tricking the program into thinking it is a repetition of the old one. The next screen will give you the option to Record FEV again. Do not record until you have read the procedure below. If you get the dialog box shown in Fig. 12.10, click NO.
Figure 12.10. Dialog box warning before the opening of a new file.

3. Place a small paper bag into a plastic produce bag. Have the test subject cover the inlet to the air flow transducer with the bags and fasten tightly enough to create an air-tight seal. *Again*, the subject should be seated facing away from the computer monitor. The subject should wear the nose clip and hold the airflow transducer by the handle with its attached filter and mouthpiece parallel to the floor. Keep the airflow transducer upright at all times (Figure 12.6).

4. The test subject should breathe normally into the filter throughout the course of the data collection process.

5. When ready, a member of the group other than the subject will click **Record FEV**. Collect respiration data for the full 300 seconds while breathing into the sack. **Important:** Anyone prone to dizziness or nausea should not be tested in this section of the experiment. If the test subject experiences dizziness, nausea, or a headache during data collection, testing should be stopped immediately.

6. Once you have finished collecting data in Step 5, measure the maximum tidal volume (valley to peak of the highest peak) and the cycle time for the intervals of 0 to 30 seconds, 120 to 150 seconds, and 240 to 270 seconds. Calculate the respiratory rate for each of these three cycles. Record this value for each section in Table 12.2.

### DATA

<table>
<thead>
<tr>
<th>Cycle</th>
<th>Before Holding Breath</th>
<th>After Holding Breath</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tidal Volume (P-P in L)</td>
<td>Cycle Time (ΔT in sec)</td>
</tr>
<tr>
<td>#1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Per Cycle Average</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory Rate (cycles/minute)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 12.2

<table>
<thead>
<tr>
<th>Cycle</th>
<th>Tidal Volume (P-P)</th>
<th>Cycle Time (ΔT)</th>
<th>Respiratory Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 30 seconds</td>
<td>________ L</td>
<td>________ seconds</td>
<td>________ cycles/min</td>
</tr>
<tr>
<td>120 to 150 seconds</td>
<td>________ L</td>
<td>________ seconds</td>
<td>________ cycles/min</td>
</tr>
<tr>
<td>240 to 270 seconds</td>
<td>________ L</td>
<td>________ seconds</td>
<td>________ cycles/min</td>
</tr>
</tbody>
</table>

**Questions**

5. Draw a sketch of the recording while breathing into a bag, indicating the changes as time progressed. Label the X-axis “Time in seconds” and the Y-axis “Volume in liters”.

6. How did the tidal volume and respiratory rate change while the test subject was breathing into the bag? What would be the significance of this change?

7. Explain how you think an increase in carbon dioxide in the blood affects your breathing. What is the mechanism?
Activity 3: Film: Deadly Ascent

High altitude poses physiological challenges. As one ascends higher, the air pressure lessens and the amount of oxygen decreases. Humans are not adapted to conditions of low levels of oxygen or extreme cold. In this film, a team is followed on its climb of Denali (also known as Mt. McKinley) and the effects of altitude and cold temperatures are observed.

Background: Climbers who ascend Denali (Mt. McKinley) can experience health problems in response to extreme conditions—high altitude, low atmospheric pressure, and severe cold. The mountain is 6,194 meters from its base to its summit. Most humans are adapted to living on earth’s surface where air pressure is about 14.7 pounds per square inch. At high elevations, because there is less oxygen in a given amount of air, humans who are not acclimated to the environment experience hypoxia, or oxygen deprivation, and they experience health complications such as hypothermia, frostbite, and sometimes gangrene due to intense wind and cold. This chart shows some air pressures at different elevations:

<table>
<thead>
<tr>
<th>Altitude (in feet)</th>
<th>Barometric Pressure (mm Hg)</th>
<th>Barometric Pressure* (in Atmospheres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (Sea Level)</td>
<td>760</td>
<td>1</td>
</tr>
<tr>
<td>3000 feet</td>
<td>684</td>
<td>0.9</td>
</tr>
<tr>
<td>10,000</td>
<td>532</td>
<td>0.7</td>
</tr>
<tr>
<td>18,000 (5,600m)</td>
<td>380</td>
<td>0.5</td>
</tr>
<tr>
<td>23,000 (7,200 m)</td>
<td>304</td>
<td>0.4</td>
</tr>
<tr>
<td>30,000 (9,400 m)</td>
<td>228</td>
<td>0.3</td>
</tr>
</tbody>
</table>


Take notes and be able to answer the following questions:

1. What conditions on Denali pose physiological challenges for climbers?
2. What is hypoxia?

3. Define and describe symptoms for
   - hypothermia
   - hyperthermia
   - Acute Mountain Sickness (AMS)
   - High Altitude Pulmonary Edema (HAPE).

4. What is oxygen saturation? How are oxygen saturation levels affected during a mountain climb? What problems can occur when the levels get too low?