LUNG VOLUMES AND CAPACITIES

STANDARDS

- **3.1.10A, 3.1.12A** – Identify the function of subsystems within a larger system; analyze and describe the function, interaction and relationship among subsystems and the system itself.
- **3.1.10B** - Apply mathematical models to science and technology.
- **3.3.10A, 3.3.12A** - Explain the relationship between structure and function at the molecular and cellular levels; explain and analyze the relationship between structure and function at the molecular, cellular and organ-system level.

INTRODUCTION

Measurement of lung volumes provides a tool for understanding normal function of the lungs as well as disease states. The breathing cycle is initiated by expansion of the chest. Contraction of the diaphragm causes it to flatten downward. If chest muscles are used, the ribs expand outward. The resulting increase in chest volume creates a negative pressure that draws air in through the nose and mouth. Normal exhalation is passive, resulting from “recoil” of the chest wall, diaphragm, and lung tissue.

In normal breathing at rest, approximately one-tenth of the total lung capacity is used. Greater amounts are used as needed (i.e., with exercise). The following terms are used to describe lung volumes (see Figure 1):

- **Tidal Volume (TV):** The volume of air breathed in and out without conscious effort
- **Inspiratory Reserve Volume (IRV):** The additional volume of air that can be inhaled with maximum effort after a normal inspiration
- **Expiratory Reserve Volume (ERV):** The additional volume of air that can be forcibly exhaled after normal exhalation
- **Vital Capacity (VC):** The total volume of air that can be exhaled after a maximum inhalation: \( VC = TV + IRV + ERV \)
- **Residual Volume (RV):** The volume of air remaining in the lungs after maximum exhalation (the lungs can never be completely emptied)
- **Total Lung Capacity (TLC):** \( = VC + RV \)
- **Minute Ventilation:** The volume of air breathed in 1 minute: \( (TV) \text{(breaths/minute)} \)

In this experiment, you will measure lung volumes during normal breathing and with maximum effort. You will correlate lung volumes with a variety of clinical scenarios.
GUIDING QUESTIONS

• What do the peaks on the experimental graph represent in terms of lung volume and capacity?
• Is there a difference in lung capacity between men and women?
• What type of clinical respiratory conditions could affect lung capacity?

SAFETY

• Do not attempt this experiment if you are currently suffering from a respiratory ailment such as the cold or flu.
• Do not attempt this experiment if you have a known chronic respiratory ailment.

MATERIALS

LabQuest w/ power supply and USB cable
Laptop w/ LoggerPro 3.6.0 or higher
Vernier Spirometer
disposable mouthpiece
disposable bacterial filter
nose clip and tissues

PROCEDURE

1. Attach the power supply to the LabQuest and plug it in. Connect the Spirometer to one of the Channel ports on the top of the LabQuest. Turn the LabQuest on by pressing the oval Power button on the upper left corner. A screen like the one in Figure 2 will appear.

2. Attach the LabQuest to the laptop with the USB cable. There are USB ports located on the back and right sides of the computer. Double click on the LoggerPro 3.6 icon on the desktop to open the program.

3. After a few seconds, LoggerPro will identify the LabQuest interface and display a screen titled “Page 1: Flow Rate Measurements”. On the left of the screen, it will show the flow rate in large red text and tips for the spirometry experiment. There will also be a graph of Time (s) vs. Flow Rate (L/s).

Note: The LabQuest is acting only as an interface for this experiment. The touch screen is not accessible when it is attached to the computer. The following instructions are meant to be carried out on the computer.
4. The experiment needs to be set to collect data for 60 s. Select **Data Collection**... from the Experiment menu. Change the length of the experiment from 20 to 60 seconds. Select Done when you are finished; the Time (s) axis will read from 0 to 60 s.

5. Attach the larger diameter side of a bacterial filter to the “Inlet” side of the Spirometer. Attach a gray disposable mouthpiece to the other end of the bacterial filter (see Figure 2).

6. Hold the Spirometer in one or both hands. Brace your arm(s) against a solid surface, such as a table, and select [ △ Zero ] from the right hand side of the tool bar. The sensor flow rate should be reading close to zero now.

**Note:** The Spirometer must be held straight up and down, as in Figure 3, and not moved during data collection.

7. Collect inhalation and exhalation data.
   a. Place a tissue or Kimwipe over your nose, then put on the nose plug.
   b. Click the green [ ▶ Collect ] button at the top of the screen to begin data collection.
   c. Taking normal breaths, begin data collection with an inhalation and continue to breathe in and out. **It is very important to start with an inhalation, as this is the trigger for data collection to begin.** After 4 cycles of normal inspirations and expirations fill your lungs as deeply as possible (maximum inspiration) and exhale as fully as possible (maximum expiration). **It is essential that maximum effort be expended when performing tests of lung volumes.**
   d. Follow this with at least one additional recovery breath.
5. Click the red [ ■ Stop ] button to end data collection.

6. Click the Next Page button, on the Tool Bar to see the lung volume data. If the baseline on your Volume graph has drifted, use the Baseline Adjustment feature to bring the baseline volumes closer to zero, as in Figure 4.

7. Select a representative peak and valley in the Tidal Volume portion of your Volume graph. Place the cursor ( ◦ ) on the peak and click and drag down to the valley that follows it. **The cursor itself must be on the graph line at both the**
peak and the valley to properly measure the volume. Enter the $\Delta y$ value displayed in the lower left corner of the graph to the nearest 0.1 L as Individual Tidal Volume in Table 1.

8. Move the cursor to the peak that represents your maximum inspiration (highest point above the zero line). Click and drag down the side of the peak until you reach the level of the peaks graphed during normal breathing (first 4 breaths). Enter the $\Delta y$ value displayed in parentheses in the lower left corner of the graph to the nearest 0.1 L as Individual Inspiratory Reserve Volume in Table 1.

9. Move the cursor to the valley that represents your maximum expiration (lowest point below the zero line). Click and drag up the side of the peak until you reach the level of the valleys graphed during normal breathing (first 4 breaths). Enter the $\Delta y$ value displayed in the lower left corner of the graph to the nearest 0.1 L as Expiratory Reserve Volume in Table 1.

10. Calculate the Individual Vital Capacity and enter the total to the nearest 0.1 L in Table 1. Use the answer to this

$$VC = TV + IRV + ERV$$

11. Calculate the Individual Total Lung Capacity and enter the total to the nearest 0.1 L in Table 1. (Use the value of 1.5 L for the RV.)

$$TLC = VC + RV$$

12. Share your data with your classmates and complete the Class Average columns in Table 1.
REFERENCES

CREDITS
The lab was revised by Dr. Stephanie Corrette-Bennett.
DATA SHEET

Table 1

<table>
<thead>
<tr>
<th>Volume measurement (L)</th>
<th>Individual (L)</th>
<th>Class average (Male) (L)</th>
<th>Class average (Female) (L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal Volume (TV)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inspiratory Reserve (IRV)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expiratory Reserve (ERV)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Vital Capacity (VC)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residual Volume (RV)</td>
<td>≈1.5</td>
<td>≈1.5</td>
<td>≈1.5</td>
</tr>
<tr>
<td>Total Lung Capacity (TLC)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

DATA ANALYSIS

1. What was your Tidal Volume (TV)? What would you expect your TV to be if you inhaled a foreign object which completely obstructed your right mainstem bronchus?

2. Describe the difference between lung volumes for males and females. What might account for this?
3. Calculate your Minute Volume at rest.

\[(TV \times \text{breaths/minute}) = \text{Minute Volume at rest}\]

If you are taking shallow breaths (TV = 0.20 L) to avoid severe pain from rib fractures, what respiratory rate will be required to achieve the same minute volume?

4. Exposure to occupational hazards such as coal dust, silica dust, and asbestos may lead to \textit{fibrosis}, or scarring of lung tissue. With this condition, the lungs become stiff and have more “recoil.” What would happen to TLC and VC under these conditions?

5. In severe emphysema there is destruction of lung tissue and reduced recoil. What would you expect to happen to Total Lung Capacity (TLC) and Vital Capacity (VC)?

6. What would you expect to happen to your Expiratory Reserve Volume when you are treading water in a lake?