Experiment
19

Lung Volumes and Capacities

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)(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.

OBJECTIVES

In this experiment, you will

- Obtain graphical representation of lung capacities and volumes.
- Compare lung volumes between males and females.
- Correlate lung volumes with clinical conditions.

MATERIALS

computer
Vernier computer interface
Logger *Pro*
Vernier Spirometer
disposable mouthpiece
disposable bacterial filter
nose clip

PROCEDURE

Important: Do not attempt this experiment if you are currently suffering from a respiratory ailment such as the cold or flu.

1. Connect the Spirometer to the Vernier computer interface. Open the file “19 Lung Volumes” from the *Human Physiology with Vernier* folder.

2. 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).

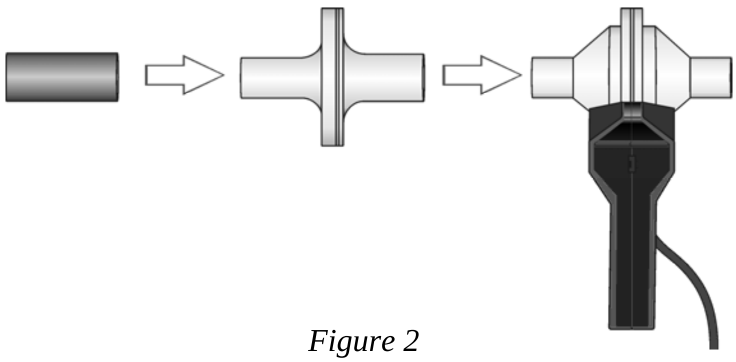


Figure 2

3. Hold the Spirometer in one or both hands. Brace your arm(s) against a solid surface, such as a table, and click [Ø Zero] to zero the sensor. **Note**: The Spirometer must be held straight up and down, as in Figure 2, and not moved during data collection.

4. Collect inhalation and exhalation data.
   a. Put on the nose plug.
   b. Click [▶ Collect] to begin data collection.
   c. Taking normal breaths, begin data collection with an inhalation and continue to breathe in and out. 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 [■ Stop] to end data collection.

6. Click the Next Page button, [⇨], to see the lung volume data. If the baseline on your graph has drifted, use the Baseline Adjustment feature to bring the baseline volumes closer to zero, as in Figure 3.

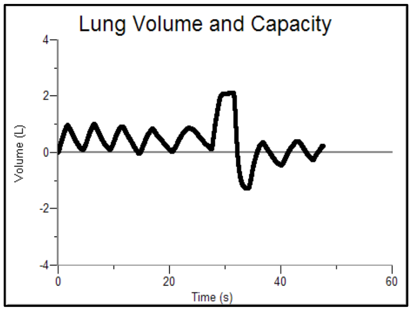


Figure 3

7. Select a representative peak and valley in the Tidal Volume portion of your graph. Place the cursor on the peak and click and drag down to the valley that follows it. Enter the Δy value displayed in the lower left corner of the graph to the nearest 0.1 L as Tidal Volume in Table 1.

8. Move the cursor to the peak that represents your maximum inspiration. Click and drag down the side of the peak until you reach the level of the peaks graphed during normal breathing. Enter the Δy value displayed in the lower left corner of the graph to the nearest 0.1 L as Inspiratory Reserve Volume in Table 1.

9. Move the cursor to the valley that represents your maximum expiration. Click and drag up the side of the peak until you reach the level of the valleys graphed during normal breathing. Enter the Δy value displayed in the lower left corner of the graph to the nearest 0.1 L as Expiratory Reserve Volume in Table 1.

10. Next you need to find the time interval of 1 breath. A breath is measured using the graph of your Tidal Volume. A breath is measured from valley to valley or peak to peak. Drag your cursor from one valley of your normal breath straight across to the next valley of your normal breath. Record your Δx. Record this time interval in Table 2.

11. Calculate the Vital Capacity and enter the total to the nearest 0.1 L in Table 1.

$$VC = TV + IRV + ERV$$

12. Calculate the 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.)

$$TLC = VC + RV$$

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

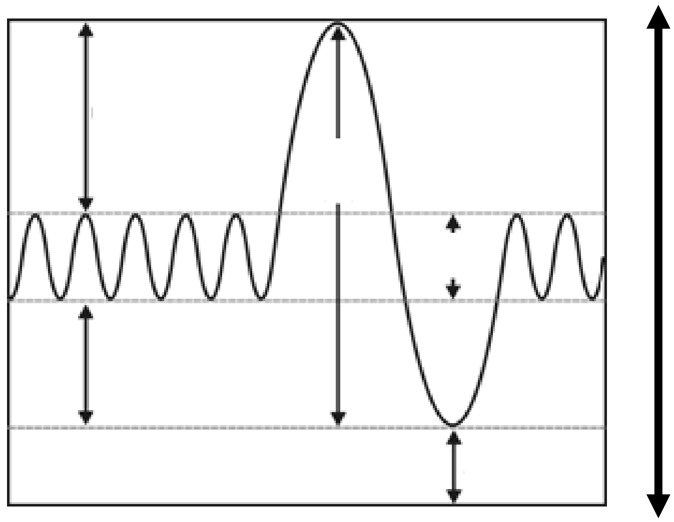
DATA

Table 1			
Volume measurement (L)	Individual (L)	Class average (Male) (L)	Class average (Female) (L)
Tidal Volume (TV)			
Inspiratory Reserve (IRV)			
Expiratory Reserve (ERV)			
Vital Capacity (VC)			
Residual Volume (RV)	≈1.5	≈1.5	≈1.5
Total Lung Capacity (TLC)			

Table 2	
	Time Interval of 1 Breath (seconds)
$\Delta x = \frac{\text{1 Breath}}{\text{Time (sec.)}}$	

DATA ANALYSIS

1. Label the Respiratory Volume Graph (Spirograph) below. Label the tidal volume, inspiratory reserve volume, expiratory reserve volume, vital capacity, residual volume, and total lung capacity.



2. 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?

   TV = ______________

3. Describe the difference between lung volumes for males and females. What might account for this?

4. Compare the data of the person in your group to the class averages for their gender. Were there any differences between your person and the class averages?

   Explain a cause as to why your person's lung volumes are different from the class averages.

5. Calculate your Minute Volume at rest. You will need to use Δ*x* from Table 2 to calculate your Minute Volume. Show your work.

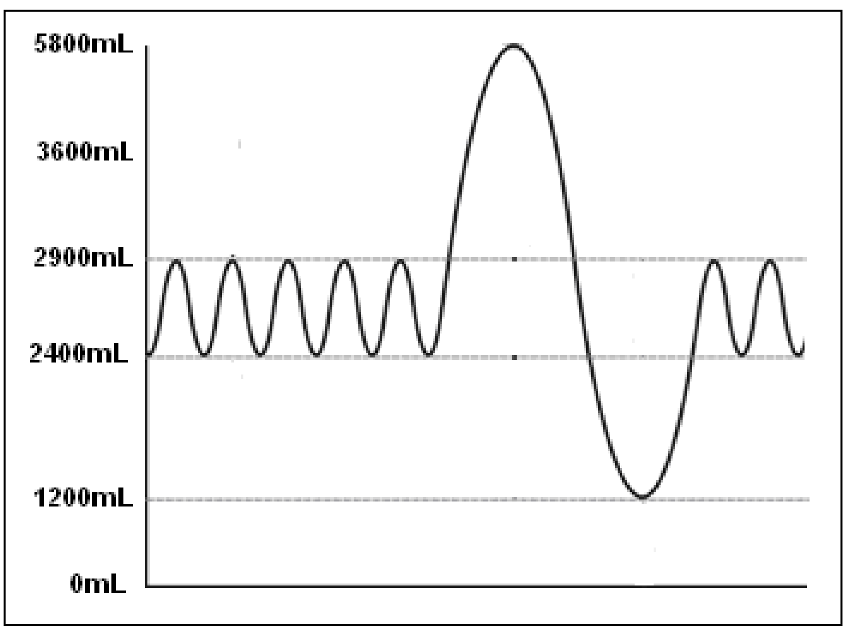
(TV × breaths/minute) = Minute Volume at rest

6. Emphysema occurs when the air sacs in your lungs are gradually destroyed, making you progressively more short of breath. Emphysema is one of several diseases known collectively as chronic obstructive pulmonary disease (COPD). Smoking is the leading cause of emphysema.

As it worsens, emphysema turns the spherical air sacs — clustered like bunches of grapes — into large, irregular pockets with gaping holes in their inner walls. This reduces the surface area of the lungs and, in turn, the amount of oxygen that reaches your bloodstream.

Emphysema also slowly destroys the elastic fibers that hold open the small airways leading to the air sacs. This allows these airways to collapse when you breathe out, so the air in your lungs can't escape. Treatment may slow the progression of emphysema, but it can't reverse the damage.

Using the graph below for comparison, draw on the spirograph the spirograph of an individual suffering from emphysema. Use a different color. Be sure to label the tidal volume, inspiratory reserve volume, expiratory reserve volume, vital capacity, residual volume, and total lung capacity of the person suffering from emphysema.



7. Based on the given actions of the diaphragm, determine the actions of the external intercostal muscles, what happens (increase or decrease) to the size, volume, and pressure of the lungs. Finally, determine the direction of air flow given the atmospheric pressure and the part of ventilation. Use Up and Down arrows to indicate increase or decrease.

Description of Action of Diaphragm	Description of Action of External Intercostal Muscles	Size of the Lungs ↓ ↑	Volume of the Lungs ↓ ↑	Alveolar Pressure ↓ ↑	Atmospheric Pressure	Direction of Air Flow (Place an **X** in the appropriate box)		Part of Ventilation
						into lungs	out of lungs	
Concave superiorly, moves upward	Thoracic cage down and in				~ 760 mmHG			
Concave inferiorly, moves downward	Thoracic cage up and out				~ 760 mmHG			

8. A person with a tidal volume of 600mL, an inspiratory reserve volume of 2900mL, and an expiratory reserve volume of 1900mL has a vital capacity of what?

9. A person with a vital capacity of 4200mL, an inspiratory reserve volume of 2400mL, and a tidal volume of 800mL has an expiratory reserve volume of what?