Cornell Institute for Biology Teachers

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Title: **Respirometry Part I: Lung Volumes and Capacities**

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Appropriate Level: Life Science, High School, Honors, or Advanced Placement Biology.

Abstract: What Are Your Volumes and Capacities?

By use of a Collins respirometer, students measure their inspiratory reserve volume, expiratory reserve volume, tidal volume and determine vital capacity. Resting measurements compared with values obtained after exercise may reveal individual homeostatic mechanisms. This exercise may be extended by pooling and analyzing class data.

Time Required: Preparation time: 5-10 min. to set up each respirometer

Class time: a minimum of 6 min. per student per respirometer. (This lab may run concurrently with the lung model lab.)

Special Notes: Special Equipment Needed: Respirometers.

Additional Teacher Information

Objectives

Upon completion of this exercise students should:

- be able to understand the volumes and capacity measurements collected.
- understand which parameters of breathing change as the bodies demand for oxygen is increased.
- discuss changes in Vital capacity associated with aging and the effects of smoking, asthma, lack of exercise, and posture have on lung volumes.

Tips for Teachers

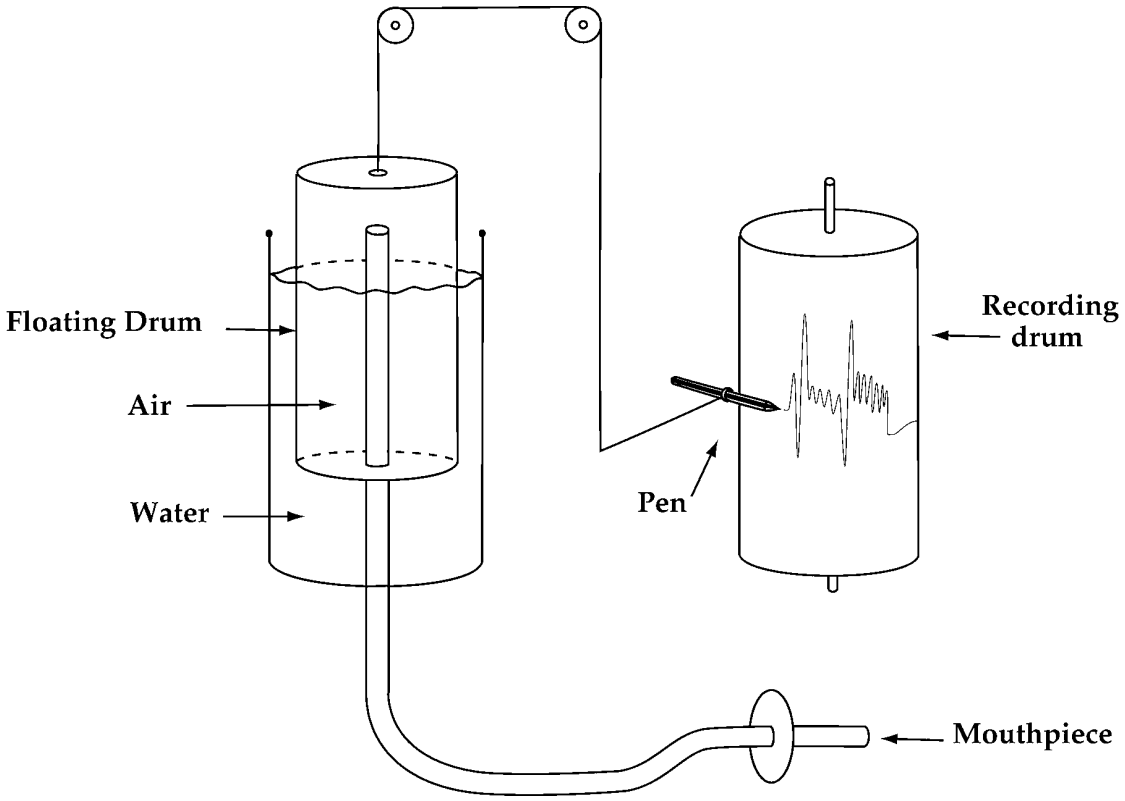
- Subjects should close their eyes or not look at the recording drum while making measurements.
- Instruct students in the application of the nose clip and stress the importance of using it. Students are reluctant to use them without encouragement.
- The data given in the text as normal values are for healthy males, 20 to 30 years old, therefore some deviation from “normal” may be expected.
- After exercise the students should only collect data for 1 - 2 minutes, and they should be instructed to stop if they feel uncomfortable and perhaps sit down while collecting the data. (There is a slight possibility that the subject may faint.)

Respirometry Part I:
Lung Volumes and Capacities

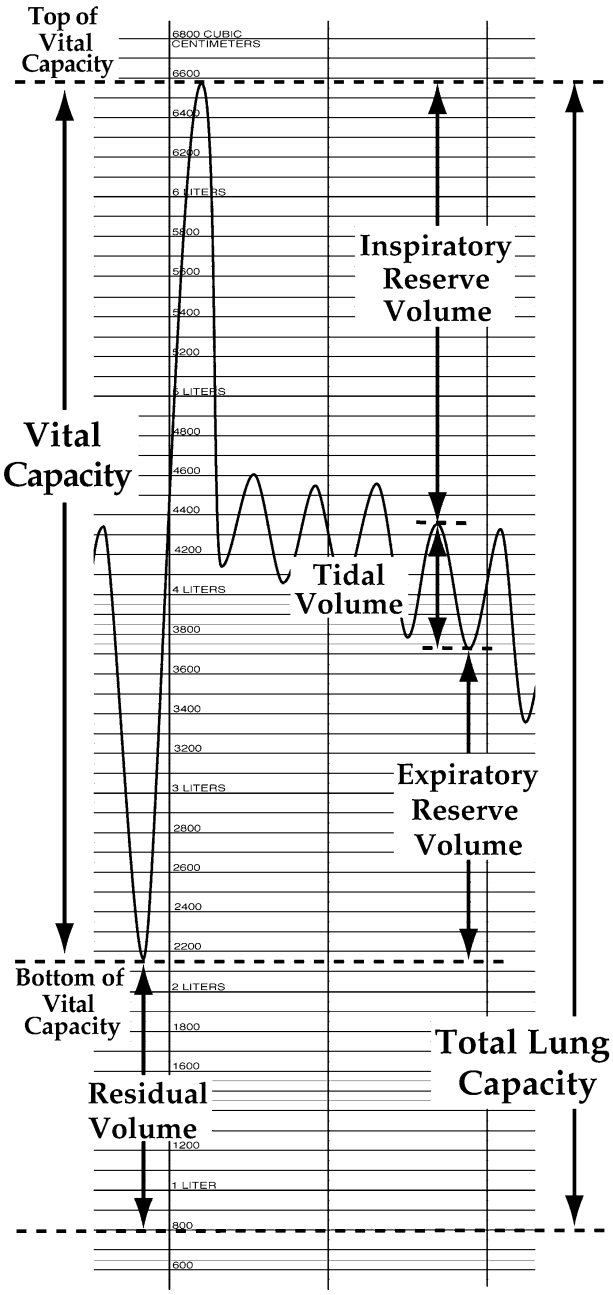
CIBT
Student Laboratory Exercise

Introduction

The respirometer is a machine that can be used to measure lung volumes and breathing rates. Changes in a person's respiratory volumes may be measured with a machine called a respirometer. The respirometer contains air inside a floating bell. The bell rises or falls when the person breathing on the machine exhales or inhales, and the pen correspondingly moves down and up on the strip chart paper. The respirometer is calibrated or "fine tuned" in a couple of ways. The vertical distance the pen moves corresponds to the volume of air you have exchanged. The horizontal distance the pen moves corresponds to the time elapsed.



Check out the "working" diagram of a respirometer above.



TIDAL VOLUME (TV) – The amount of air exchanged in normal breathing is called tidal volume. The average tidal volume while resting is 50 ml.

EXPIRATORY RESERVE VOLUME (ERV) – The amount of air that can be forcefully exhaled after a tidal expiration is called the expiratory reserve volume. At rest this amount is about 1000 ml.

INSPIRATORY RESERVE VOLUME (IRV) – The amount of air that can be forcefully inspired after tidal inspiration is called the inspiratory reserve volume. While resting this amount can be 3000 ml. The IRV can vary greatly; heavy breathing due to exercise usually erodes the IRV while adding to the TV.

RESIDUAL VOLUME (RV) – The amount of air left in the lungs after maximal forced exhalation is called the redisual volume. This air can never b willfully emptied and is about 1500 ml. (This volume can be measured using inert gasses, like helium.)

VITAL CAPACITY (VC) – The maximum amount of air that can be exhaled by a person after inhaling fully is called the vital capacity. This amount is about 4500 ml and is equal to ERV + TV + IRV.

TOTAL LUNG CAPACITY (TLC) – The total volume of air the lungs can hold is called the total lung capacity. This volume is about 6000 ml and is equal to ERV + TV IRV + RV or more simply RV + VC.

Pulmonary disorders can be diagnosed and assessed by volume and capacity measurements and by pulmonary flow rates. There are two broad categories of related disease: 1. restrictive diseases, such as fibrosis, and 2. obstructive diseases, such as emphysema and asthma. Restrictive diseases are diagnosed, in part, by volume and capacity data, while obstructive diseases may rely on flow rates (volume of gas exchange per unit time).

Procedure

The "breather" breathes into the respirometer, while the coaches monitor the machine and the breather. **This is not a solo effort.** The coaches' encouragement and assistance to the breather is critical for accurate data collection.

1. Refresh the air in the bell by gently pushing the bell all the way down and raising it almost all the way up. Use the bell to position the pen toward the middle of the chart paper.

2. Remove the drum from the machine. The holder at the top of the drum pulls upward to release the drum. Install a piece of chart paper on the drum with tape.

3. The subject installs a new disposable mouthpiece on the spirometer hose and uses a nose clamp to prevent nasal breathing. He or she should sit comfortably and adjust the hoses for themselves; the subject **should not watch** the chart while measurements are being made.

4. Practice breathing into the machine.

    - Use the "juicy" part of your lips to ensure a tight seal.

    - No leakage of air should occur.

5. Turn the drum speed to the medium position (160 mm/min.), turn on machine if on/off switch is present. Refresh the air in the bell.

6. The breather needs to close his/her eyes and "check out."

To coach the breather:

- Ask the breather to breathe normally into the respirometer for about 5 breaths.

- After the last exhale, strongly encourage the breather to inspire (breathe in) maximally. (Come on! Pull it in!)

- Strongly encourage the breather to expire (breathe out) maximally. BLOW IT OUT!!

- Return to normal breathing and repeat a, b, and c, so that two tracings of this breathing pattern can be made.

  (Note: If the pen goes off the scale on the paper at all during breathing, readjust the start position for the pen and repeat procedure.

7. Turn off the rotating drum. Label the tracing as "resting." The subject should be instructed to remove the nose clamp and do 2 minutes of vigorous exercise, either jumping jacks or stationary running. Immediately after exercise, replace nose clamp and repeat the procedure on the same chart paper.

8. Have the coaches and breather exchange roles and repeat the entire procedure.

Pulmonary Volumes and Capacities

Determine the following data from your chart paper, and the **instructions which follow. Do calculations in the data table. Label units.**

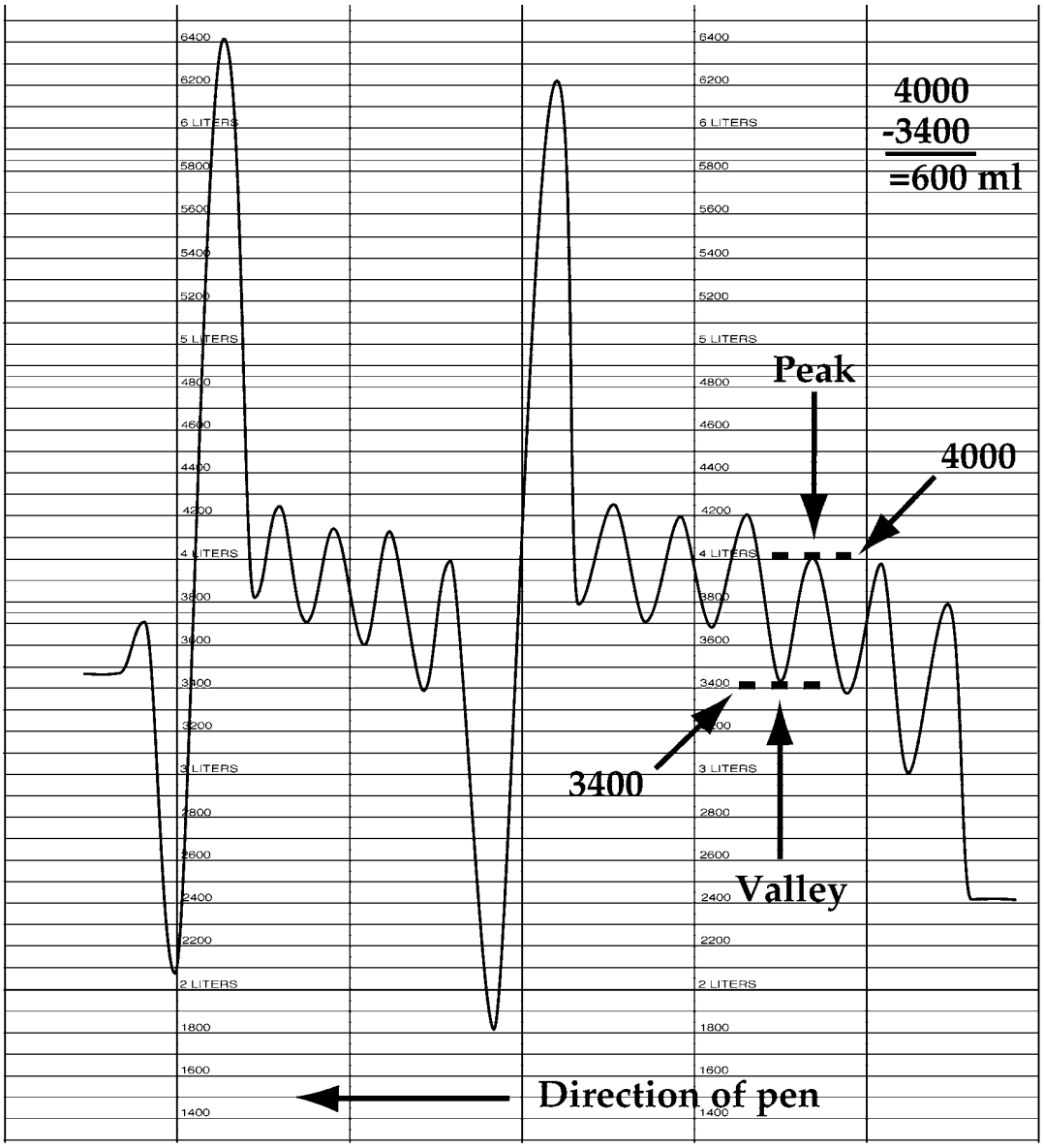
	Tidal Volume	Vital Capacity	Inspiratory Reserve Volume	Expiratory Reserve Volume	Breathing Rate
Resting					
Exercise					

How to Measure Volumes

- Chart paper can be used to measure breathing volumes.
- Breathing volumes are measured in **milliliters**.
- There are 1000 ml. in 1 liter.
- Each horizontal line on this chart paper represents 50 ml.
- Each peak represents one breath.

1. Select **one average sized** normal breath to determine the following:

   - To calculate the tidal volume, mark the peak and valley of the breath selected.
   - To subtract the valley volume from the peak volume. The difference equals the volume of one breath.



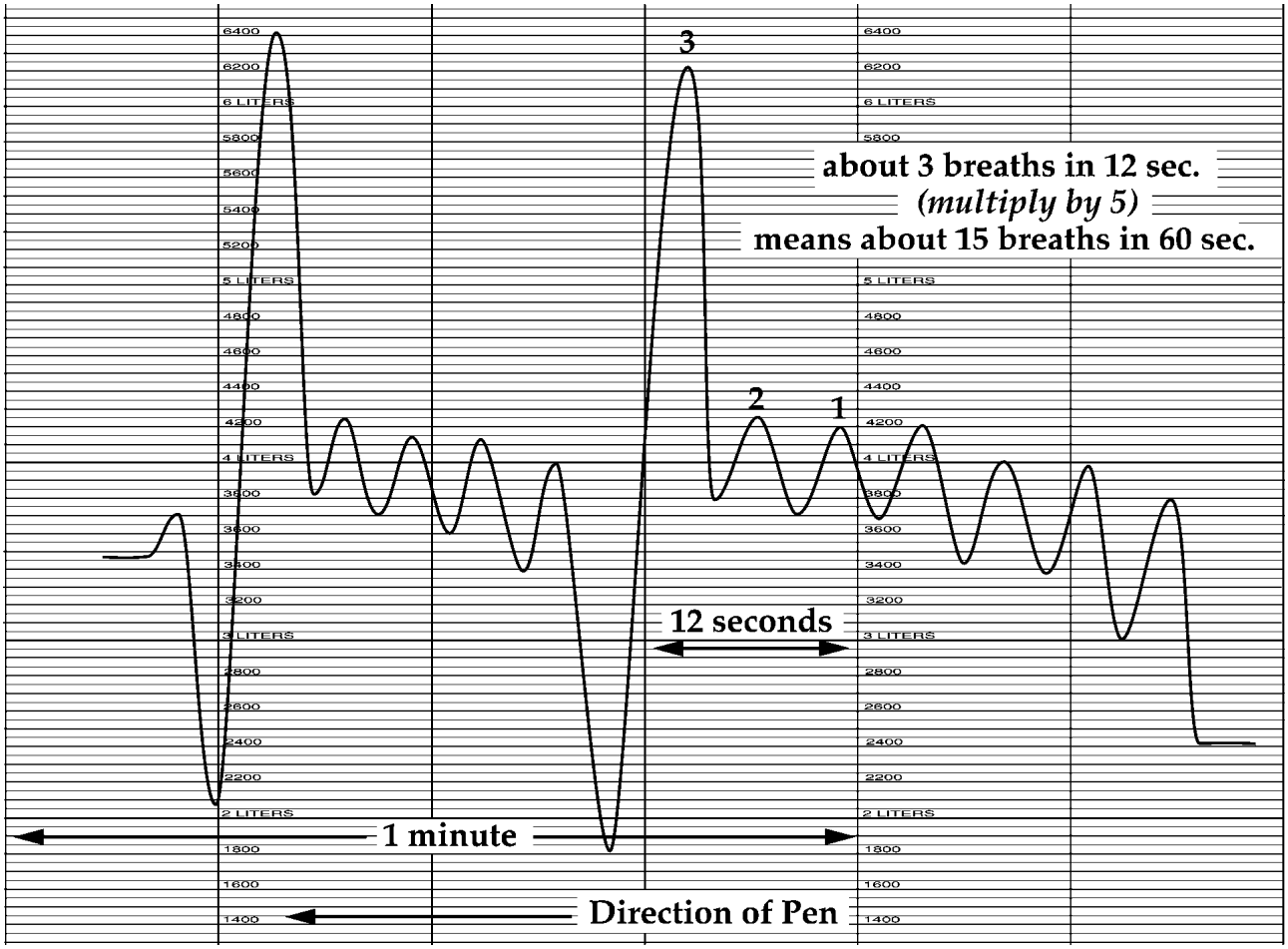
2. To determine vital capacity, choose the largest vital capacity on your tracing and repeat the procedure of marking and subtracting peak and valley volumes.

3. Using the peaks and the valleys of the vital capacity and the tidal volume you selected, determine the inspiratory reserve volume and the expiratory reserve volume.

How to Measure Breathing Rate

1. If speed control is set at 160 mm/min., then the time it takes for the pen to move from one vertical line to the next vertical line is 12 seconds.

2. Each vertical line = 12 seconds, therefore, 5 vertical lines = 60 sec. (1 min.). (5 x 12 = 60)



3. To calculate the # of breaths per minute, count the # of peaks in 12 seconds and multiply by 5.

OR: $\frac{\text{\# breaths}}{\textbf{12 sec.}} = \frac{\text{? breaths}}{\textbf{60 sec.}}$

Name:_____ Date:_____

Lab Questions

1. How do your resting and exercise tidal volumes compare? Give an explanation.

2. How do vital capacity measurements compare at rest and after exercise? Give an explanation.

3. Vital capacity is determined by the size of your chest cavity and the condition of your lungs. Would you expect the vital capacity to change? (Think about this!!) Why or why not?

4. Compare expiratory reserve volumes and inspiratory reserve volumes at rest and after exercise.

    a. Did the IRV in #4 increase or decrease after exercise? Give a possible explanation for any changes observed.

b. Did the ERV in #4 increase or decrease after exercise? Give a possible explanation for any changes observed.

5. What is Residual Volume (RV)?

6. Calculate your resting total lung capacity (TLC) using the equation given in the background information. Assume RV is 1500 ml.

7. Draw a graph (bar, circle or line) on a separate piece of paper that compares your resting TV, ERV, IRV, VC, and TLC with the values given in the background information of the lab.

8. What effect might body size have on vital capacity and why?

9. How might poor posture affect lung volume?

10. Turn your respirometer paper over. Check out the strange chart called "Spirometry in Normal Females, Prediction Nomograms." Check out the chart for males next to it. Place a ruler so that it connects the places for your age and your height. Read the number where the ruler crosses the column labeled FVC (forced vital capacity). Is this greater or lesser than the VC you calculated? Do you think FVC and VC are related? Why?

11. What is the most interesting thing you learned from this lab?