Human Respiration Lab

Objectives:

- To understand the microscopic and gross anatomy of the respiratory tract
- To observe and measure the mechanics of breathing, respiratory volumes, and the control of breathing
- To observe and understand the role of buffers in maintaining pH balance in the body

Introduction:

Breathing is an involuntary event. Humans, when they are not exerting themselves, breathe approximately 15 times per minute on average. The primary function of the respiratory system is to deliver oxygen to the cells of the body’s tissues and remove carbon dioxide, a cell waste product. Oxygen (O$_2$) diffuses into the cells where it is used for metabolic reactions that produce ATP, a high-energy compound. At the same time, these reactions release carbon dioxide (CO$_2$) as a byproduct. CO$_2$ is toxic in high amounts and must be eliminated. CO$_2$ diffuses out of the cells, enters the bloodstream, travels back to the lungs, and is expired out of the body during exhalation.

The main structures of the human respiratory system are the nasal cavity, the trachea, and lungs.
Exercise 1: Mechanism of breathing (balloon-and-bell jar model)

Materials
Balloon-and-bell jar

Procedure

- Pull down the rubber sheet. What happens to the balloons? _________________. This represents the downward movement of the human ________________, which causes the chest cavity to become ________________________ (larger/smaller). This, in turn, causes the human __________________________ to expand and fill with air.

- Release the rubber sheet. What happens to the balloons? _________________. This represents relaxed ________________ (inhaling/exhaling), when the chest cavity becomes smaller and the lungs deflate. Note that this is a passive process.

- What organs do the balloons represent? _________________________________
Exercise 2: Breathing Measurements

During inhalation, volume increases as a result of contraction of the diaphragm, and pressure decreases (according to Boyle’s Law). This decrease of pressure in the thoracic cavity relative to the environment makes the cavity less than the atmosphere. Because of this drop in pressure, air rushes into the respiratory passages. To increase the volume of the lungs, the chest wall expands. The chest wall expands out and away from the lungs. The lungs are elastic; therefore, when air fills the lungs, the elastic recoil within the tissues of the lung exerts pressure back toward the interior of the lungs. These outward and inward forces compete to inflate and deflate the lung with every breath. Upon exhalation, the lungs recoil to force the air out of the lungs, and the intercostal muscles relax, returning the chest wall back to its original position. The diaphragm also relaxes and moves higher into the thoracic cavity. This increases the pressure within the thoracic cavity relative to the environment, and air rushes out of the lungs. The movement of air out of the lungs is a passive event. No muscles are contracting to expel the air.

![Diagram of Inhalation and Exhalation]

The lungs, chest wall, and diaphragm are all involved in respiration, both (a) inhalation and (b) expiration.

- Put one hand on your chest and take three deep inspirations followed by three forced expirations. Describe your observation during each inspiration and expiration.

- Repeat Step 1 with your hands on your abdomen. Now try to breathe in and out without any movement of your chest. Describe your observation during each inspiration and expiration.
Exercise 3: Measurements of breathing in resting and active modes

The number of breaths per minute is the respiratory rate. On average, under non-exertion conditions, the human respiratory rate is 12–15 breaths/minute. The respiratory rate contributes to the alveolar ventilation, or how much air moves in and out of the alveoli. Alveolar ventilation prevents carbon dioxide buildup in the alveoli. When a person consciously holds her/his breath for a long period of time, the CO₂ level rises which causes the pH of the blood to decrease. This stimulates the respiratory center and reflex breathing occurs. As CO₂ is removed, the reaction proceeds to the left, thus removing hydrogen ions and forming more CO₂ for liberation from the body.

Materials
Per group (2): Timer

Procedure
The purpose of the following exercises is to investigate some of the factors that affect the rate and depth of breathing.

| CAUTION |
| Do not do the following activities if you have any medical problems with your lung or heart. All subjects should stop immediately if they feel faint. |

1. Time how long you can hold your breath after a quiet inspiration. ____________ sec.

2. Time how long you can hold your breath after a deep inspiration (inhale as deeply as possible, then hold your breath). ____________ sec

3. Time how long you can hold your breath following a quiet expiration. ________ sec

4. Breathe deeply and forcefully at a rate of about 1 breath/3 seconds, 20 times (hyperventilate). Time how long you can hold your breath. ____________ sec

5. Run down the hall and back again or go down to the first floor and come back up quickly.

Then immediately hold your breath for as long as possible. Record the time. ________ sec

During which procedure could you hold your breath the longest? ________________
Exercise 4: Measuring Lung Volumes and Capacities

Human lung size is determined by genetics, gender, and height. At maximal capacity, an average lung can hold almost six liters of air, but lungs do not usually operate at maximal capacity. Air in the lungs is measured in terms of **volumes** and **capacities**. Volume measures the amount of air for one function (such as inhalation or exhalation). Capacity is any two or more volumes (for example, how much can be inhaled from the end of a maximal exhalation).

![Diagram of lung volumes and capacities](image)

<table>
<thead>
<tr>
<th>Volume/Capacity</th>
<th>Definition</th>
<th>Volume (liters)</th>
<th>Equations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal volume (TV)</td>
<td>Amount of air inhaled during a normal breath</td>
<td>0.5</td>
<td>-</td>
</tr>
<tr>
<td>Expiratory reserve volume (ERV)</td>
<td>Amount of air that can be exhaled after a normal exhalation</td>
<td>1.2</td>
<td>-</td>
</tr>
<tr>
<td>Inspiratory reserve volume (IRV)</td>
<td>Amount of air that can be further inhaled after a normal inhalation</td>
<td>3.1</td>
<td>-</td>
</tr>
<tr>
<td>Residual volume (RV)</td>
<td>Air left in the lungs after a forced exhalation</td>
<td>1.2</td>
<td>-</td>
</tr>
<tr>
<td>Vital capacity (VC)</td>
<td>Maximum amount of air that can be moved in or out of the lungs in a single respiratory cycle</td>
<td>4.8</td>
<td>ERV+TV+IRV</td>
</tr>
<tr>
<td>Inspiratory capacity (IC)</td>
<td>Volume of air that can be inhaled in addition to a normal exhalation</td>
<td>3.6</td>
<td>TV+IRV</td>
</tr>
<tr>
<td>Functional residual capacity (FRC)</td>
<td>Volume of air remaining after a normal exhalation</td>
<td>2.4</td>
<td>ERV+RV</td>
</tr>
<tr>
<td>Total lung capacity (TLC)</td>
<td>Total volume of air in the lungs after a maximal inspiration</td>
<td>6.0</td>
<td>RV+ERV+TV+IRV</td>
</tr>
<tr>
<td>Forced expiratory volume (FEV1)</td>
<td>How much air can be forced out of the lungs over a specific time period, usually one second</td>
<td>~4.1 to 5.6</td>
<td>-</td>
</tr>
</tbody>
</table>
Materials
Per group (2): nose clip (optional); simple spirometer; disposable mouth piece

Procedure
1. **Measure Tidal Volume (TV)**
   - Place a disposable mouthpiece over the stem of the spirometer.
   - We have several different styles of spirometer. If the spirometer has tick marks all the way around, set the dial to zero. If the spirometer has a gap between 0 and 1000, set the dial to 1000.
   - Hold your nose so that all of the air expired from your lungs enter the spirometer. Sit and breathe quietly for a moment. Expire into the spirometer. **Do not force any air out of your lungs.** Count the number of tick marks the dial moved and multiply by 100. Record this value below. Repeat two more times.

   Trial 1_____________ ml   Trial 2 ____________ ml   Trial 3 ____________ ml
   - Average your measurements:

     TV: _________________ml

2. **The minute respiratory volume (MRV) represents the volume of air moving in and out of your lungs in 1 minute during normal, quiet respiration.**
   - Determine your normal respiratory rate (RR) for 1 min by counting the number of breaths (remember, a breath is inhale + exhale) : RR: _______ (normal RR = ~12 breaths per minute)
   - To determine your MRV, multiply your RR x TV.

     MRV = _________________ml per minute

3. **Measure Expiratory Reserve Volume (ERV)**
   - After three normal breaths, **ending** in expiration, hold your nose and **forcefully** expel all of the air left in your lungs into the spirometer. Count the number of tick marks the dial moved and multiply by 100. Record this value below. Repeat two more times.

   Trial 1_____________ ml   Trial 2 ____________ ml   Trial 3 ____________ ml
   - ERV: ____________________ml
4. **Measure Vital Capacity (VC)**
   - After three deep breaths, take one final deep inspiration. Then hold your nose and exhale as much air as possible into the spirometer. **Note:** A slow, even, forced expiration works best. Repeat two more times. Count the number of tick marks the dial moved and multiply by 100. Record this value below.

   Trial 1_____________ ml   Trial 2 ______________ ml   Trial 3 _____________ ml

   VC: ____________________ml

5. **Inspiratory Capacity (IC)** can be calculated using the following formula
   \[ IC = VC - ERV = \underline{\text{________________________}} \text{ml} \]

6. **Inspiratory Reserve Volume (IRV)** can be calculated using the following formula
   \[ IRV = IC - TV = \underline{\text{________________________}} \text{ml} \]

7. **Residual Volume (RV)** can be calculated using the following formula
   \[ RV = VC \times \text{Age Factor} = \underline{\text{________________________}} \text{ ml} \]
   
   Age Factors: age 16–34 = 0.25; age 35–49 = 0.31; age 50–69 = 0.45

8. **Total lung capacity (TLC)** can be calculated using the following formula
   \[ TLC = TV + IRV + ERV + RV = \underline{\text{________________________}} \text{ ml} \]

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Your Data</td>
<td>Average</td>
</tr>
<tr>
<td>Tidal volume (TV)</td>
<td>500</td>
<td>375</td>
</tr>
<tr>
<td>Inspiratory reserve volume (IRV)</td>
<td>3000</td>
<td>2250</td>
</tr>
<tr>
<td>Expiratory reserve volume (ERV)</td>
<td>1000</td>
<td>750</td>
</tr>
<tr>
<td>Residual volume (RV)</td>
<td>1200</td>
<td>900</td>
</tr>
<tr>
<td>Total Lung Capacity (VC + RV)</td>
<td>5700</td>
<td>4275</td>
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Balloon and bell-jar image from [https://commons.wikimedia.org/wiki/File:Bell_jar_lungs.png](https://commons.wikimedia.org/wiki/File:Bell_jar_lungs.png). All other materials from [Rice University](https://www.rice.edu) and is licensed under a [Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License](https://creativecommons.org/licenses/by-nc-sa/4.0/).