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

PART 1:
Microscopic Examination of Respiratory Tissue
- Obtain viewmaster Set 72, Respiratory System and examine images 2 through 6.
- No sketches are necessary. Note especially the alveoli of the respiratory tract in image 5 and the capillary networks in image 6.

PART 2:
Mechanics of Breathing
- Observe the balloon-and-bell jar model (a standard demonstration of the mechanics of breathing).
- 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? ________________________________________________

PART 3:
Measuring Respiratory Volumes and Lung Capacity
Respiratory volumes are measured with an apparatus called a spirometer. There are two types of spirometers - wet and dry. We will use a simple, hand-held, dry type spirometer called a Propper Spirometer. Although it is limited in that it cannot measure inhalation, it will provide us with some information in determining certain respiratory volumes and lung capacities. It is important to remember, however, that the volumes and capacities vary even in normal people depending on age, size, and sex.

Procedure
1. Measure Tidal Volume (TV)
- Swab the stem of the spirometer with an alcohol swipe and place a disposable mouthpiece over it.
- Rotate the dial to 1000. This 1000 ml will be subtracted from each measurement.
- 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. Record your measurement and repeat two more times. ______, ______, ______
- Average your measurements and subtract 1000 from the total volume recorded.

TV: __________________ml
2. **Determine Respiratory Rate and Calculate Minute Respiratory Volume (MRV)**

   The 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: RR: __________________ (normal RR = ~12)
   - To determine your MRV, multiply your RR x TV.
     
     \[
     \text{MRV} = \underline{\text{_______________}} \text{ml per minute}
     \]

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. Repeat two more times. Average your measurements and subtract 1000 from the total volume recorded. _____, _____, _____
     
     \[
     \text{ERV: } \underline{\text{_______________}} \text{ml}
     \]

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.
   - If time permits, repeat two more times and take an average. Subtract 1000 from the volume recorded. _____, _____, _____
     
     \[
     \text{VC: } \underline{\text{_______________}} \text{ml}
     \]

5. **Inspiratory Capacity (IC) can be calculated using the following formula**

   \[
   \text{IC} = \text{VC} - \text{ERV} = \underline{\text{_______________}} \text{ml}
   \]

6. **Inspiratory Reserve Volume (IRV) can be calculated using the following formula**

   \[
   \text{IRV} = \text{IC} - \text{TV} = \underline{\text{_______________}} \text{ml}
   \]

Respiratory volumes vary according to size, physical condition, age, and sex. However, you are on the right track if your figures come out something like this:

<table>
<thead>
<tr>
<th></th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal volume</td>
<td>500</td>
<td>375</td>
</tr>
<tr>
<td>Inspiratory reserve volume</td>
<td>3000</td>
<td>2250</td>
</tr>
<tr>
<td>Expiratory reserve volume</td>
<td>1000</td>
<td>750</td>
</tr>
<tr>
<td>Vital capacity</td>
<td>4500</td>
<td>3375</td>
</tr>
<tr>
<td>Residual volume</td>
<td>1200</td>
<td>900</td>
</tr>
<tr>
<td>Total lung capacity</td>
<td>5700</td>
<td>4275</td>
</tr>
</tbody>
</table>
PART 4: Control of Respiration
Respiration and Acid/Base Balance
We normally breathe without thinking about it. Our respiratory rate also usually adjusts to changes in our activity levels without any conscious effort on our part. The changes in breathing, both rate and depth, are largely regulated by chemical changes in the blood. For example, when a person consciously holds her/his breath for a long period of time, the carbon dioxide level rises which causes the pH of the blood to decrease. The following reaction illustrates this concept:

\[
\text{H}_2\text{O} + \text{CO}_2 \rightleftharpoons \text{H}_2\text{CO}_3 \rightleftharpoons \text{H}^+ + \text{HCO}_3^- 
\]

As the CO₂ levels increase in the blood, H₂CO₃ (carbonic acid) forms which then dissociates to form HCO₃⁻ (bicarbonate ion) and release H⁺ (hydrogen ions), resulting in a decrease in pH (more acidic). 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. Normally, the rate of CO₂ production by the tissues of the body (end product of metabolism) is matched to the respiratory rate. This keeps the carbonic acid, bicarbonate ion, and the hydrogen ion concentration within the normal range.

**Hypoventilation** is defined as slow, shallow breathing that results in a buildup of carbon dioxide in the lungs. The above reaction will move to the right, resulting in a buildup of hydrogen ions. This will lead to a decrease in blood pH that may result in respiratory acidosis. On the other hand, **hyperventilation** is defined as rapid, deep breathing that results in blowing off large quantities of CO₂ with little change in the amount of O₂ being exchanged. This results in an increase in blood pH to a point where the desire to breath is eliminated until the CO₂ level rises above some critical point. This decrease in CO₂ will cause vasoconstriction of the cerebral vessels and the lack of O₂ will result in cerebral anoxia. Both these effects may lead to a feeling of dizziness during hyperventilation.

Respiration can be voluntarily inhibited for a period of time, but eventually the voluntary control is overridden by the buildup of CO₂ levels and the decrease in O₂ levels. The purpose of the following exercises is to investigate some of the factors that affect the rate and depth of breathing.

**Procedure**
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? _________________

**Question**: Using the background information provided previously, explain why.

**More on Breathing and Acid-Base Balance**
1. Obtain a 250ml beaker, distilled water, 0.05 M NaOH, phenol red solution (with dropper), and a straw.
2. Add 50ml distilled water plus 2.5ml 0.05 M NaOH and 2 drops of phenol red to the beaker.
3. Select one individual from your group to blow bubbles into the straw through the solution. Remind this individual that you do not want to aspirate (draw) the liquid into the straw. Inhalations should be taken with the mouth removed from the straw.

4. Observe the color of the solution and record how long it takes for the pH indicator to change from pink/red to yellow. Phenol red is a pH indicator that turns yellow in acidic solutions and pink in basic solutions.
   Time: _________________________

5. Now repeat the experiment using the sodium bicarbonate buffer solution. Add 50 ml distilled water, 2.5 ml 0.05 M NaOH, 5 ml buffer solution, and 2 drops phenol red to the beaker. The SAME individual needs to again blow bubbles into the solution.
   Time: _________________________
   Compare the times between the two trials. Why are they different?

Identify each of the designated components of the respiratory tract in the illustration below. Match and enter the letter of the correct function of each component.

<table>
<thead>
<tr>
<th>Component</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>bronchial tree</td>
<td>Airway where sound is produced; closed off while swallowing</td>
</tr>
<tr>
<td>diaphragm</td>
<td>Muscle sheet between thoracic cavity and abdominal cavity with role in breathing</td>
</tr>
<tr>
<td>epiglottis</td>
<td>Closes off larynx during swallowing</td>
</tr>
<tr>
<td>intercostal muscles</td>
<td>Supplemental airway when breathing is labored</td>
</tr>
<tr>
<td>larynx</td>
<td>Airway that connects larynx with two bronchi</td>
</tr>
<tr>
<td>nasal cavity</td>
<td>Chamber in which air is warmed, moistened, and filtered, and in which sounds resonate</td>
</tr>
<tr>
<td>oral cavity</td>
<td>Airway that connects nasal cavity and mouth with larynx; also connects with esophagus</td>
</tr>
<tr>
<td>pleural membrane</td>
<td>Membranes that separate lungs from other organs; has fluid-filled cavity in between</td>
</tr>
<tr>
<td>pharynx</td>
<td>Lobed, elastic organ of breathing that enhances gas exchange between internal environment and the outside air</td>
</tr>
<tr>
<td>trachea</td>
<td>Increasingly branched airways between two bronchi and alveoli</td>
</tr>
<tr>
<td>trachea</td>
<td>Lobed, elastic organ of breathing that enhances gas exchange between internal environment and the outside air</td>
</tr>
</tbody>
</table>

A. Airway where sound is produced; closed off while swallowing
B. Muscle sheet between thoracic cavity and abdominal cavity with role in breathing
C. Increasingly branched airways between two bronchi and alveoli
D. Closes off larynx during swallowing
E. Chamber in which air is warmed, moistened, and filtered, and in which sounds resonate
F. Ribcage muscles with roles in breathing
G. Airway that connects larynx with two bronchi
H. Supplemental airway when breathing is labored
I. Membranes that separate lungs from other organs; has fluid-filled cavity in between
J. Airway that connects nasal cavity and mouth with larynx; also connects with esophagus
K. Lobed, elastic organ of breathing that enhances gas exchange between internal environment and the outside air