Breathing

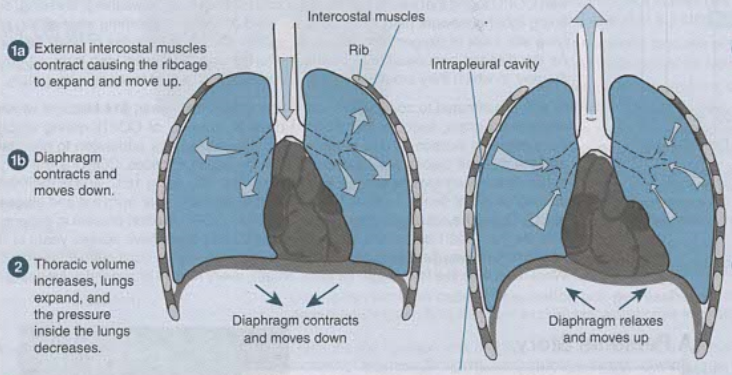
Breathing (ventilation) provides a continual supply of fresh air to the lungs and helps to maintain a large diffusion gradient for **respiratory gases** (oxygen and carbon dioxide) across the gas exchange surface. Oxygen must be delivered regularly to supply the needs of respiring cells. Similarly, carbon dioxide, which is produced as a result of cellular metabolism, must be quickly eliminated. Adequate lung ventilation is essential to these exchanges. The cardiovascular system participates by transporting respiratory gases to and from the cells of the body. The volume of gases exchanged during breathing varies according to the physiological demands placed on the body (e.g. by exercise).

Inspiration (inhalation or breathing in)

During quiet breathing, inspiration is achieved by increasing the space (therefore decreasing the pressure) inside the lungs (and alveoli). Air then flows into the alveoli in response to the decreased pressure. Inspiration is always an active process involving muscle contraction.

Expiration (exhalation or breathing out)

During quiet breathing, expiration is achieved passively by decreasing the space (thus increasing the pressure) inside the lungs. Air then flows passively out of the lungs. In active breathing, muscle contraction is involved in bringing about both inspiration and expiration.



The intrapleural pressure (the pressure inside the intrapleural cavity) is always negative and relatively large, whereas alveolar (intrapulmonary) pressure moves from slightly positive to slightly negative as a person breathes. This allows the alveolar pressure to exert force and stop the lungs collapsing.

1. Explain the purpose of breathing: _____

2. (a) Describe the sequence of events involved in quiet breathing: _____

   (b) Explain the essential difference between this and the situation during heavy exercise or forced breathing:

3. Identify what other gas is lost from the body in addition to carbon dioxide: _____

4. Explain the role of the elasticity of the lung tissue in normal, quiet breathing: _____

5. Under normal circumstances, the intrapleural pressure is always negative:

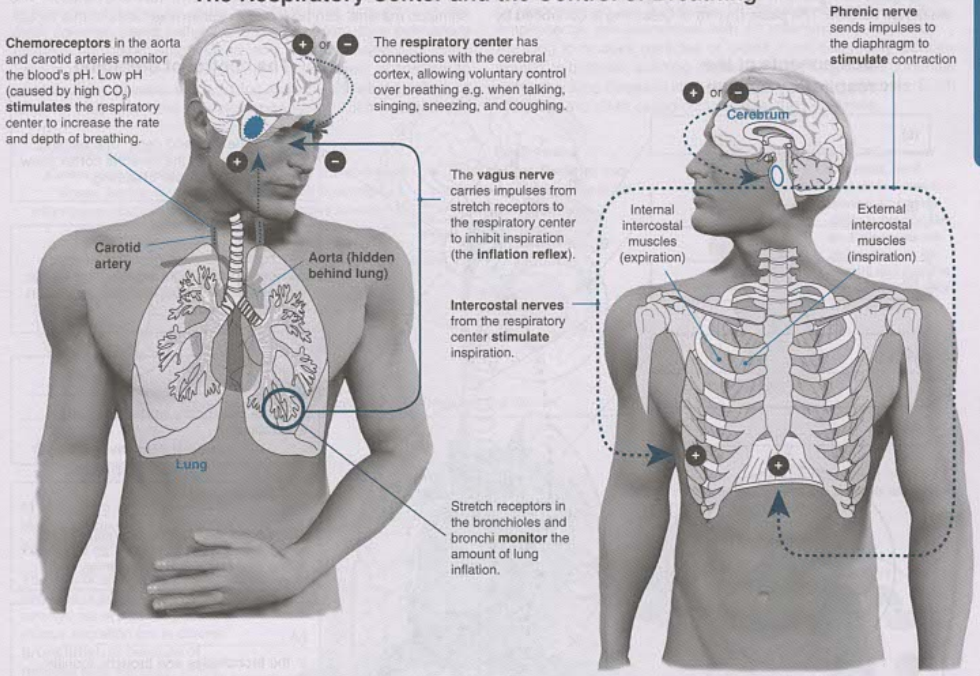
   (a) What would happen to the intrapleural pressure if someone was punctured through the chest wall (a pneumothorax)?

   (b) What would then happen to the lung on that side? _____

Control of Breathing

The basic rhythm of breathing is controlled by the **respiratory center**, a cluster of neurons located in the medulla oblongata. This rhythm is adjusted in response to the physical and chemical changes that occur when we carry out different activities. Although the control of breathing is involuntary, we can exert some degree of conscious control over it. The diagram below illustrates these controls.

The Respiratory Center and the Control of Breathing



Sensory input
Stretch receptors in the bronchioles monitor lung inflation and send impulses to inhibit the respiratory center. Input from sensory receptors and the higher brain centers influence the basic rhythm.

Motor output
The respiratory center sends rhythmic impulses to the intercostal muscles and the diaphragm to bring about breathing.

1. Explain how the basic rhythm of breathing is controlled: _____

2. Describe the role of each of the following in the regulation of breathing:

   (a) Phrenic nerve: _____

   (b) Intercostal nerves: _____

   (c) Vagus nerve: _____

   (d) Inflation reflex: _____

3. (a) Describe the effect of low blood pH on the rate and depth of breathing: _____

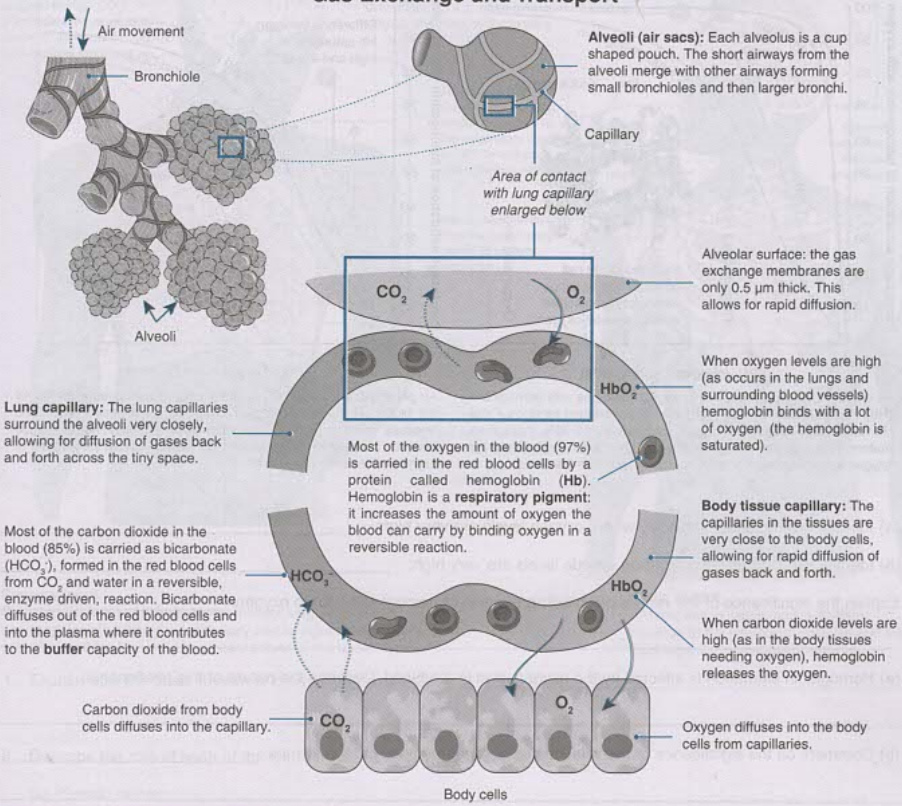
   (b) Explain how this effect is mediated: _____

   (c) Suggest why blood pH is a good mechanism by which to regulate breathing rate: _____

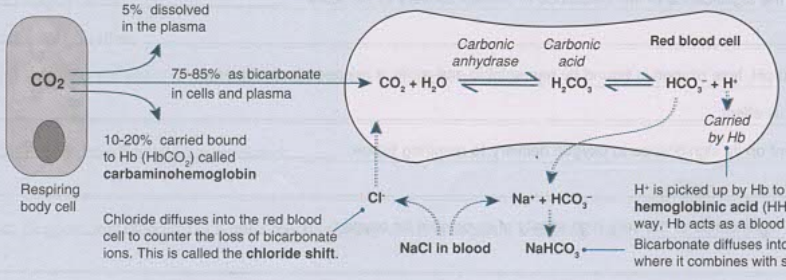
Gas Transport

The transport of respiratory gases around the body is the role of the blood and its respiratory pigments. Oxygen is transported throughout the body chemically bound to the respiratory pigment **hemoglobin** inside the red blood cells. In the muscles, oxygen from hemoglobin is transferred to and retained by **myoglobin**, a molecule that is chemically similar to hemoglobin except that it consists of only one heme-globin unit. Myoglobin has a greater affinity for oxygen than hemoglobin and acts as an oxygen store within muscles, releasing the oxygen during periods of prolonged or extreme muscular activity. If the myoglobin store is exhausted, the muscles are forced into oxygen debt and must respire anaerobically. The waste product of this, lactic acid, accumulates in the muscle and is transported (as lactate) to the liver where it is metabolized under aerobic conditions.

Gas Exchange and Transport



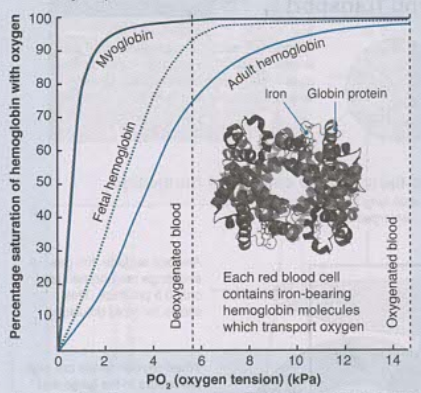
Transport of carbon dioxide in the blood



Oxygen does not easily dissolve in blood, but is carried in chemical combination with hemoglobin (Hb) in red blood cells. The most important factor determining how much oxygen is carried by Hb is the level of oxygen in the blood. The greater the oxygen tension, the more oxygen will combine with Hb. This relationship can be illustrated with an oxygen-hemoglobin dissociation curve as shown below (Fig. 1). In the lung capillaries, (high O_2), a lot of oxygen is picked up and bound by Hb. In the tissues, (low O_2), oxygen is released. In skeletal muscle, myoglobin picks up oxygen from hemoglobin and therefore serves as an oxygen store when oxygen tensions begin to fall. The release of oxygen is enhanced by the **Bohr effect** (Fig. 2).

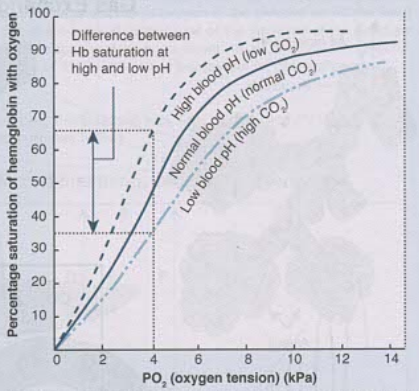
Respiratory Pigments and the Transport of Oxygen

Fig.1: Dissociation curves for hemoglobin and myoglobin at normal body temperature for fetal and adult human blood.



As oxygen level increases, more oxygen combines with hemoglobin (Hb). Hb saturation remains high, even at low oxygen tensions. Fetal Hb has a high affinity for oxygen and carries 20-30% more than maternal Hb. Myoglobin in skeletal muscle has a very high affinity for oxygen and will take up oxygen from hemoglobin in the blood.

Fig.2: Oxygen-hemoglobin dissociation curves for human blood at normal body temperature at different blood pH.



As pH increases (lower CO_2), more oxygen combines with Hb. As the blood pH decreases (higher CO_2), Hb binds less oxygen and releases more to the tissues (the **Bohr effect**). The difference between Hb saturation at high and low pH represents the amount of oxygen released to the tissues.

1. (a) Identify two regions in the body where oxygen levels are very high: _____

   (b) Identify two regions where carbon dioxide levels are very high: _____

2. Explain the significance of the **reversible binding** reaction of hemoglobin (Hb) to oxygen: _____

   _____

3. (a) Hemoglobin saturation is affected by the oxygen level in the blood. Describe the nature of this relationship:

   _____

   (b) Comment on the significance of this relationship to oxygen delivery to the tissues: _____

   _____

4. (a) Describe how fetal Hb is different to adult Hb: _____

   (b) Explain the significance of this difference to oxygen delivery to the fetus: _____

   _____

5. At low blood pH, less oxygen is bound by hemoglobin and more is released to the tissues:

   (a) Name this effect: _____

   (b) Comment on its significance to oxygen delivery to respiring tissue: _____

   _____

6. Explain the significance of the very high affinity of myoglobin for oxygen: _____

   _____

7. Identify the two main contributors to the buffer capacity of the blood: _____