Pulmonary Ventilation Respiratory Volumes and Capacities

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Pulmonary Ventilation

Pulmonary (Pulmon: lung) ventilation or breathing is the mechanical flow of air into (inspiration) and out of (expiration) the lungs. During breathing, the contraction and relaxation of muscles act to change the volume of the thoracic cavity by which the volume of the lungs and the pressure inside change corrspondingly. Mammalian lungs work through **negative pressure ventilation**. The pressure inside the lungs is always 5 mm to 8 mm Hg less than atmospheric pressure. This negative pressure, is enough to keep them expanded and prevents them from collapsing. Ventilation of lungs takes place in two steps:

Inhalation : Inhalation or inspiration as you can see from Fig. 2.8(a) is initiated by the diaphragm and is supported by the external intercostals muscles. Under normal conditions (Fig. 2.8 a), the diaphragm, is the primary driver of inhalation. When the diaphragm contracts, the intercostal muscles contract, and elevate the sternum and ribs. As a result the ribcage expands and the contents of the abdomen are moved downwards. This results in a larger thoracic volume and negative (suction) pressure (with respect to atmospheric pressure) inside the thorax. As the pressure in the chest falls, atmospheric air moves into the mouth and from it into the air conducting tubes. Here, the air is filtered, warmed, and humidified as it flows to the lungs. Normal resting respirations are 10 to 18 breaths per minute, with a time period of 2 seconds

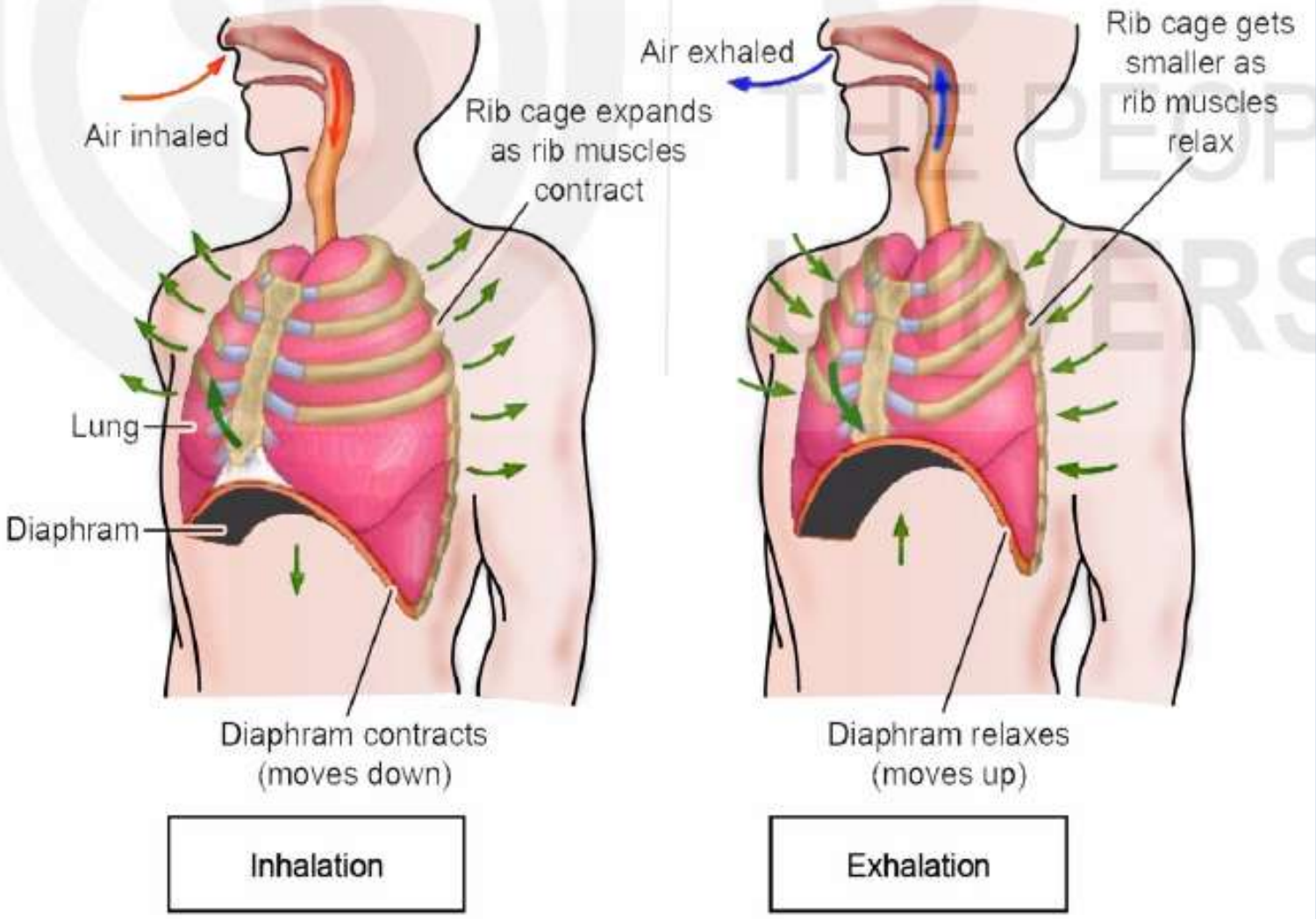

Fig 2.8: Pulmonary ventilation during respiration: a) inhalation in which the diaphragm contracts and move down; and b) exhalation in which the diaphragm relaxes and moves up.

Exhalation : Exhalation or expiration is generally a passive process (Fig. 2.8 b). The diaphragm returns to its resting position and the intercostals muscles relax, depressing the sternum and ribs. The lungs have a natural elasticity and so as they recoil back from the stretch of inhalation and their return to their normal position, air flows back to outside from them into the atmosphere till the pressures in the chest and the atmosphere reach an equilibrium. However, active or forced exhalation can be voluntority achieved by the abdominal and the internal intercostals muscles. During active the process of active or ford inhabit air is forced our or exhaled out. During forced exhalation, as when blowing out a candle, expiratory muscles including the abdominal muscles and internal intercostals muscles generate abdominal and thoracic pressure, which forces air out of the lungs.

Lung Volumes and Capacities

An average lung at rest maximum capacity can hold 6 liters of air, but lungs do not operate at maximum capacity. The total space within the lungs is measured in terms of lung volumes and lung capacities. Lung volume measures the amount of air required for one function of the lung that is, volume of inspired air, while lung capacity is the sum of two or more volumes. During the normal course of respiration when you breathe out or during exhalation, the exhaled air coming out from, some of the used air deficient in oxygen remains in the connecting tubes *i.e.*, trachea, bronchi and their branches is of the lungs and when you breathe in or inspire space occupied by the used air that remain in this used air is pushed back into the lungs first, before the fresh air enters. The volume of used present in air in the air passags thus reduce the volume of fresh air that can enter the lungs. Therefore, the space is called **anatomical dead space** and the volume occupied by this used air is learned. The **dead space** volume and is 150 ml. Let us look at some definitions related to lung volumes and capacities with the help of Table 2.2. You can see from the table that the volume of air inhaled in one breath at rest is 500 ml, therefore only 350 ml (500-150=350) of fresh air reaches the alveoli. In exercise the dead space volume is insignificant as an adult male may inhale 3000 ml of air in a single breath, in which case 150 ml is hardly significant.

Table 2.2 : Respiratory volumes and capacities in men. The pulmonary volume and capacities are usually 20-25% less in women.

Terms	Definition	Normal Volumes
Tidal volume (TV)	The volume of air inhaled and expired in one breath at rest.	500 ml
Inspiratory reserve volume (IRV)	The additional volume of air that can be taken in by forced inspiration, over and above the tidal volume.	3000 mL.
Expiratory reserve volume (ERV)	The volume of air in excess of tidal volume that can be exhaled forcibly.	1100 mL.
Residual volume (RV)	The volume of air which remains in the lungs after maximum expiration.	1200mL.
Vital capacity (VC)	The sum of inspiratory reserve volume, tidal volume and expiratory reserve volume. (IRV+TV+ERV)	4600 mL
Inspiratory capacity (IC)	Volume of air that can be inhaled in addition to a normal exhalation. (TV+IRV)	3500 mL
Total Lung capacity.	Total volume of air in the lungs after a maximal inspiration (The sum of TV+IRV+RV+ERV)	5800 mL

No matter how hard one may try the lungs are never empty of air. There is still about 1200 ml of air left in it. This is the **residual volume** after maximum expiration. If the lungs were emptied out completely the lung surfaces would stick together and the energy required to re-inflate them would be huge. During inhalation 350 ml of fresh air reaches and mixes with the 1200 ml of the residual air. This ensures that that there is a constant composition of 15% O_2 and 5% CO_2 in the lungs. This remains the same even during exercise and the extra requirement of O_2 is met by the extra ventilation of the lungs.

The lung/respiratory volumes and capacities are studied for diagnosis of respiratory disease. These respiratory volumes are obtained by using an instrument called the spirometer. However, the residual volume cannot be measured and can only be calculated.