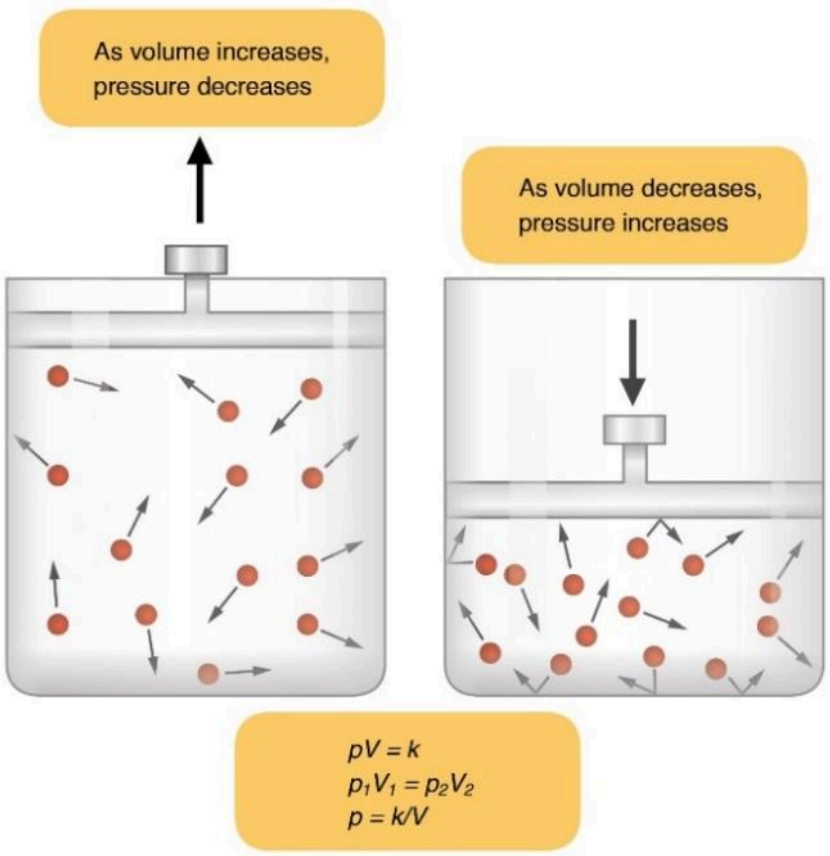
5.2.1

Ventilation: Inspiration and Expiration

Under quiet resting conditions the respiratory rate is about 12 breaths per minute. This air movement or ventilation is necessary from moment to moment to sustain life. From the metabolism chapter in BIO 264, we learned that to make sufficient ATP from glucose or other nutrient molecules, we have to inhale oxygen so that it might be reduced and accept hydrogens and electrons to form water. We also learned that carbon dioxide is a byproduct of nutrient molecule breakdown and that we actually "breathe out" part of the molecules of the food we eat (the carbons in CO_2 you're breathing out were part of the glucose in the Snickers bar you ate). The process of moving air from the external environment into the lungs is called inspiration. Expiration is air moving from the lungs out of the body into the environment. As described previously, air will always move from a region of high pressure to a region of lower pressure. The question, then, is what actually brings about the pressure differences to ensure air movement into and out of the lungs? The answer lies in the relationship between pressure and volume described by Robert Boyle.

Boyle's Law

Boyle's law is P = k/V, where P is the pressure of a gas, V is the volume of the gas, and k is a constant. This equation shows that there is an inverse relationship between pressure and volume. It shows that if the volume of a container of gas decreases, the pressure exerted by that gas will increase.



Boyle's Law.

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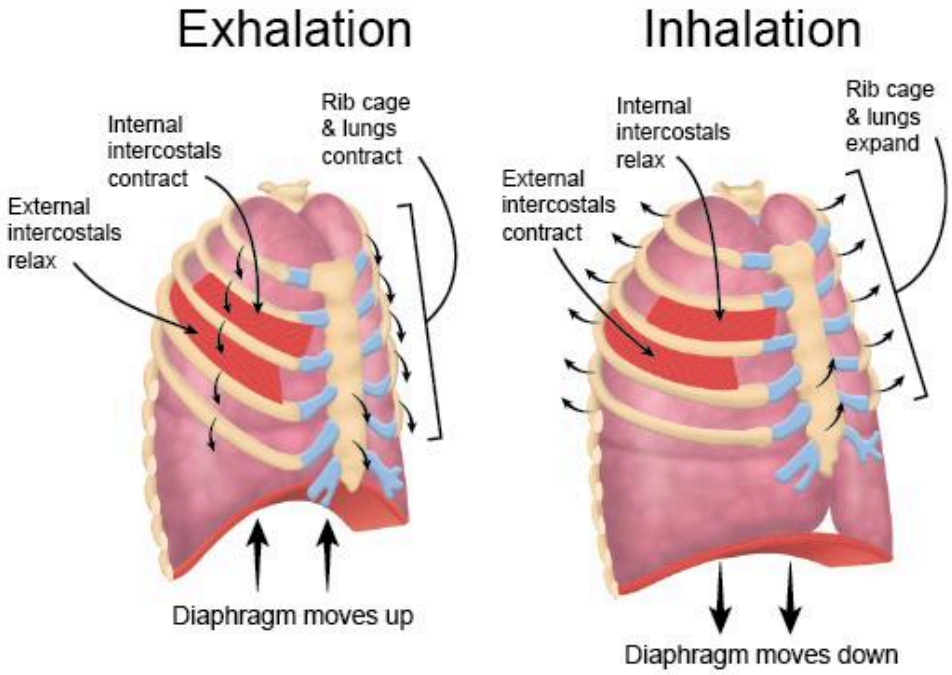
https://cnx.org/contents/FPtK1zmh@8.80:u67b9E14@8/The-Process-of-Breathing

A good example is a bicycle tire. If you pump air into a bicycle tire you are forcing air into a much smaller volume than the same number of air molecules would occupy if they were floating in the atmosphere. Essentially, you have increased the pressure in the tire by confining the molecules to a much smaller space. Likewise, the body allows ventilation or air movement to happen by changing the volume of the thoracic cavity. For inspiration to happen there has to be a lower pressure inside the lungs compared to the atmosphere. This is achieved by increasing the volume of the thoracic cavity. To do this we use muscles to change the size of the internal space inside the thoracic cavity.

The two main muscles of quiet inspiration are the diaphragm and the external intercostal. The diaphragm, in its relaxed state, is dome-shaped. When it contracts it moves inferiorly and assumes a flattened shape pushing down on abdominal organs. This inferior movement of the diaphragm increases the volume inside the thoracic cavity by increasing the height or vertical dimension of the cavity. Under resting conditions, about 2/3 of the volume increase leading to inspiration is due to depression of the diaphragm. The rest comes from contraction of the external intercostals. This action elevates the ribs and sternum, increasing thoracic cavity volume in the anterior-posterior dimension, as well as the medial-lateral dimension.



Muscles of Respiration. *Image created by BYU-I student Nate Shoemaker Spring 2016*

Thoracic cavity dimensions increase when the ribs and sternum elevate. Increases in dimensions in these previously mentioned planes results in increased lung volume of about 500 ml under quiet-breathing conditions. Alveolar pressure is now negative (-1 atm) relative to atmospheric, so air rushes into the lungs and inspiration happens. Inspiration stops when the pressures are equalized and alveolar pressure is equal to atmospheric pressure. Contraction of the external intercostals is also important to stiffen the thoracic cage and prevent collapse of the cavity during inspiration. Accessory muscles including the sternocleidomastoid, scalene muscles, and pectoralis minor are additionally important during more labored, intense breathing with exercise or in certain lung diseases to more fully, and rapidly elevate the ribs and sternum to increase inspiration rate and volume. Are you a little out of breath after reading this paragraph? Take a deep breath cause we're going back in.

During quiet expiration, the movement of air out of the lungs is due to the relaxation of the muscles of inspiration as well as the elastic nature of the lungs and surface tension. The diaphragm relaxes and reassumes its dome-shape and the external intercostals relax, depressing the ribs. Elastic recoil and surface tension forces in the alveoli cause the lungs to assume a smaller volume. This makes alveolar pressure now greater than atmospheric pressure causing the higher-pressure gasses inside the lungs to move out resulting in expiration. Forcing expiration involves contraction of the internal intercostals and the oblique and transverse abdominal muscles. The internal intercostals cause more rapid rib depression and contracting abdominals push the internal organs against the diaphragm to cause it to more rapidly assume its resting dome-shape.

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