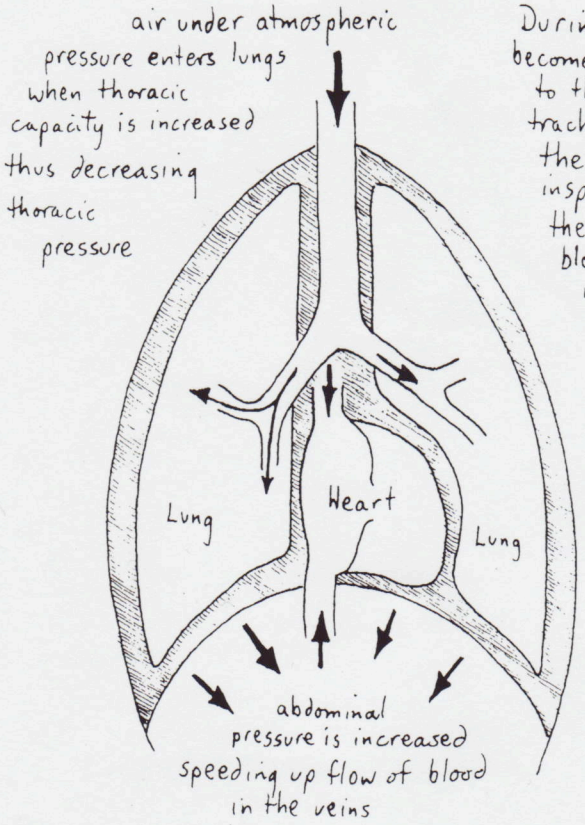
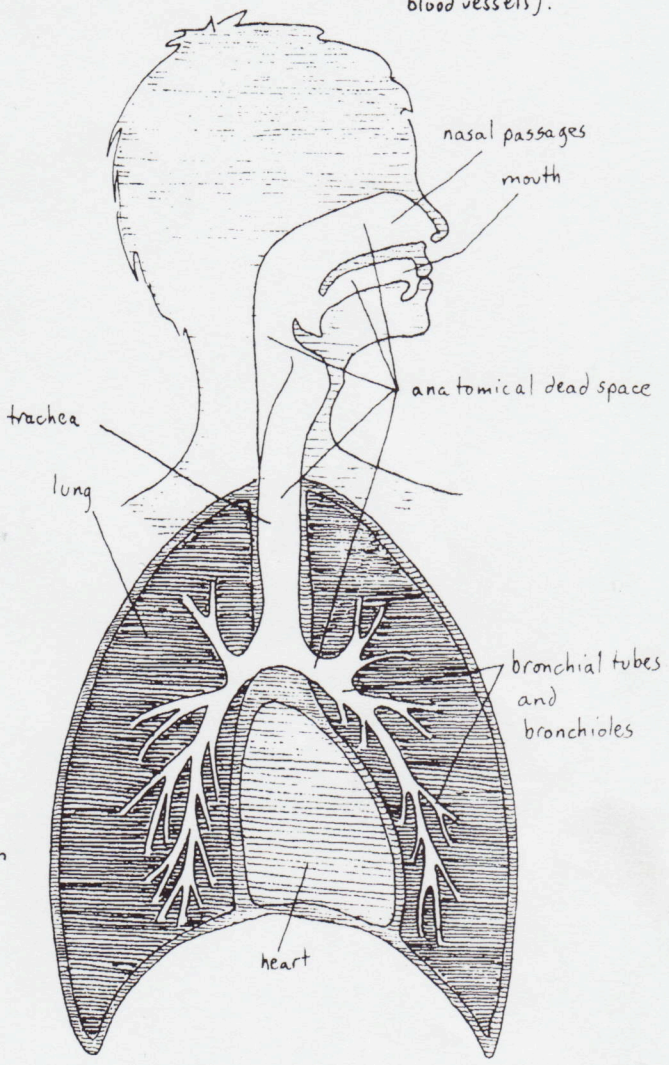
from: David Jordan "The Body Moveable" 1981



During inspiration the intrathoracic pressure falls and becomes less than that of the outside but also less relative to the abdominal cavity. As a result air enters the trachea and lungs and the venous return of blood to the right atrium of the heart is speeded up. Thus, inspiration improves cardiac filling, and with help of the lesser circulation into the lungs brings venous blood into contact with the newly inspired air. Thus inspiration at once ensures fresh air entry and pulmonary vascular perfusion (filling of the lung blood vessels).



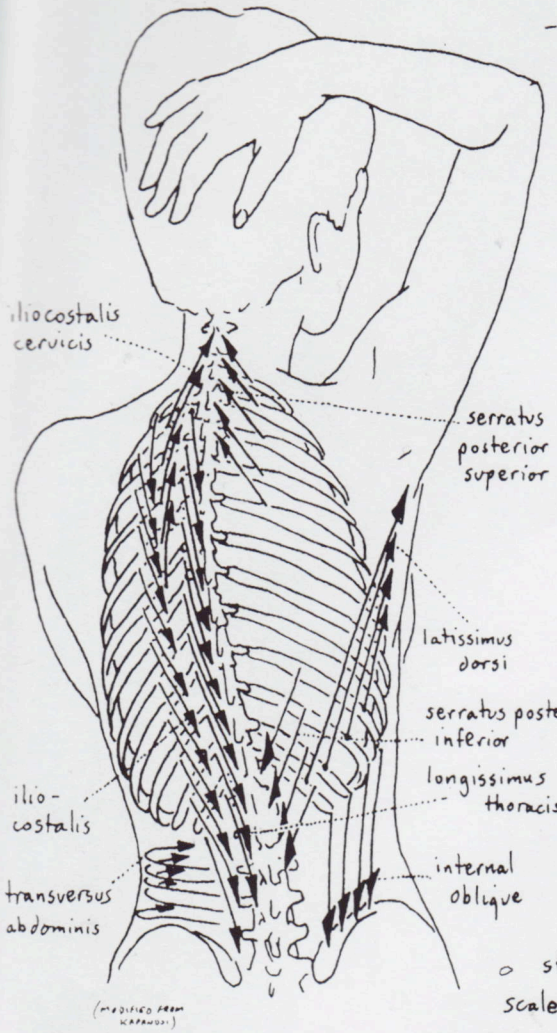
In quiet respiration about 500-750 ml. of air is inspired or expired in each respiratory cycle (the tidal volume). About one/third of this occupies the anatomical dead space. This space extends from the nostrils and mouth into the trachea, bronchi and bronchioles where practically no gaseous exchange with the blood can occur. The remainder of the inspired air is available for ventilation of the alveoli. The dead space amounts to about 150 ml. The inspired air is warmed, humidified and filtered in the nasal cavity.

The Respiratory Muscles

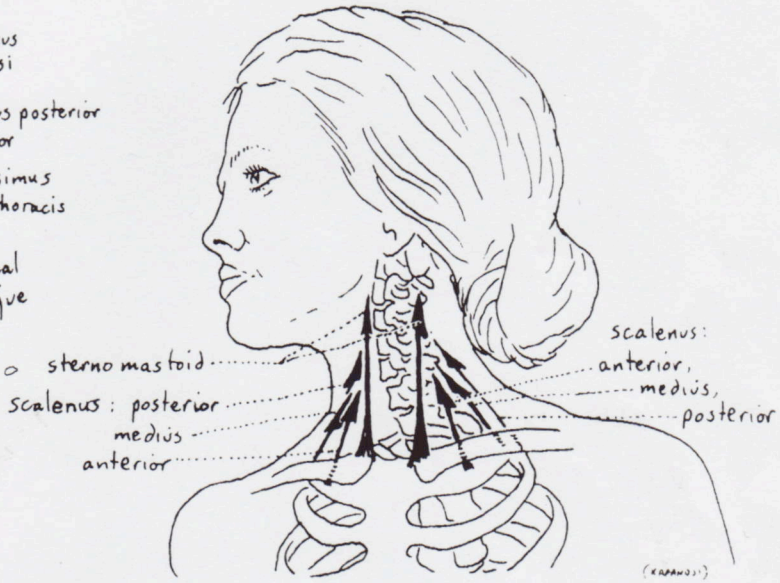
The respiratory muscles can be divided into two groups: muscles of inspiration which elevate the ribs; and muscles of expiration which depress the ribs and sternum. These can be further subdivided in two groups - the primary and the accessory muscles, the latter being recruited only when the respiratory movements are unusually deep or strong.

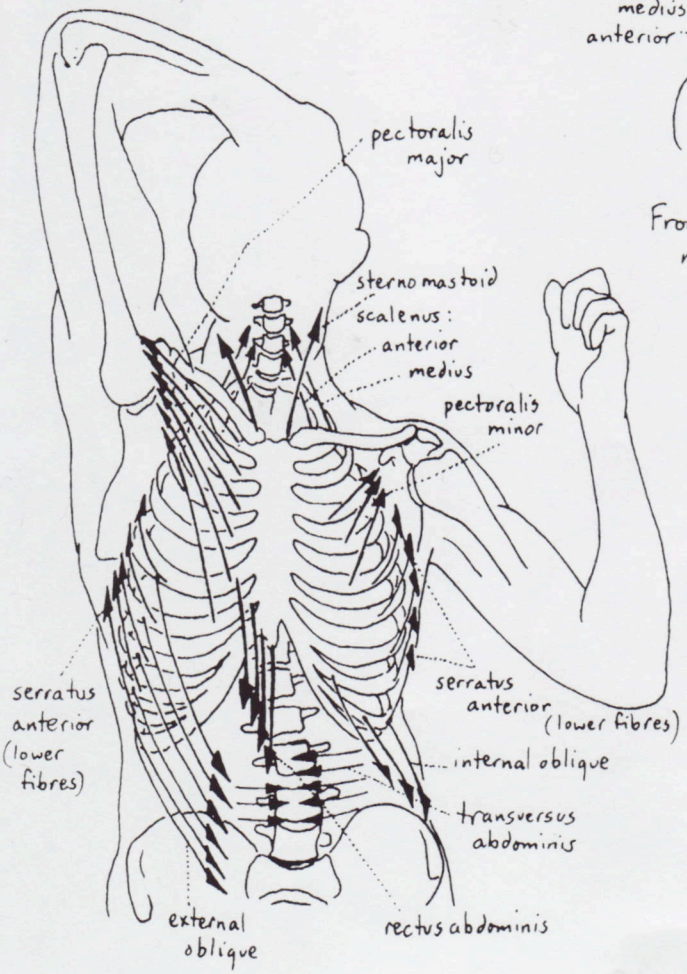
The primary inspiratory muscles - the external intercostals and above all the diaphragm - have been covered above.

The accessory inspiratory muscles which can act to elevate the ribs include: - the sternomastoid, the scalenus anterior, medius and posterior (see pages 178, 176 for full coverage) only help in inspiration when they can act on the cervical vertebral column which has been fixed by other muscles.



- the pectoralis major and minor (see volume 2 pages 36, 37) when they act on the scapula and upper limb already in abduction.
- the inferior fibres of serratus anterior and latissimus dorsi (see vol. 2, pages 38, 34) when the latter acts on the upper limb already abducted.
- the serratus posterior inferior may help in inspiration
- iliocostalis cervicis (see page 62) which is attached superiorly to the last five cervical transverse processes and inferiorly to the first six costal angles. It resembles levator costarum in the direction of its fibres.





From the above list of accessory inspiratory muscles it can readily be seen why those having difficulty breathing have a tendency to hunch up the shoulders and pull back and fix the neck to provide a high, stable point from which these muscles can work.

The primary expiratory muscles are the internal intercostals, though in quiet expiration the elastic recoil of the lungs and chest plays the major role. The internal intercostals are aided by the intercostalis intimi and subcostals

The accessory expiratory muscles are no less important and are extremely powerful

- the abdominal muscles: rectus abdominis, external oblique, internal oblique and transversus abdominis pull down on the lower ribs and force the diaphragm upwards.

- in the thoracolumbar region other accessory muscles are present; the lowest fibres of iliocostalis and of longissimus, the serratus posterior inferior and the quadratus lumborum.

In quiet inspiration the principal and often the sole muscle concerned is the diaphragm. In an average adult the right cupola descends to the level of the disc between T_{10} and T_{11}; the left between T_{11} and T_{12}. The dome descends about 1.5 cm. This diaphragmatic movement is responsible for the greater part, perhaps sometimes all of the tidal volume of about 500 ml. There is usually little or no variation in the position of the bony boundaries of the thoracic inlet. Electromyography shows, however, rhythmic activity in the scalenes (anterior and medius) which serves to fix the upper ribs while the intercostal muscles of the upper six spaces may show continuous activity, thereby preventing the sucking in or blowing out of the tissues of these spaces with changes in the interpleural pressure. At the same time the intercostals of the lower spaces may undergo rhythmic contraction, thereby contributing to the increase of the transverse diameter at this level of the cage.

In quiet expiration the elastic recoil of the lungs and chest wall is graduated by the slow relaxation of the inspiratory muscles. Electromyography demonstrates that the diaphragm and the intercostals continue contracting but with progressively decreasing intensity well into the expiratory phase. Another component believed to be important in the recoil of the lungs is the surface tension of a thin film at the interface between the alveolar air and the lung surface. Provided the ventilation rate is below 40 litres per minute there is no active participation of the intercostal or abdominal muscles in expiration.

In deep inspiration the movements already described are increased and additional muscles are brought into action. The muscles contract with greater force, the number of motor units called into action increases, the discharges along their nerves are of longer duration and the contribution of the different motor units is better synchronized. The intercostal muscles become active in an increasing number of intercostal spaces to produce movements of the upper ribs and sternum. The 1st rib is elevated by scalenus anterior and medius and by the sternocleidomastoid indirectly through the clavicle and costoclavicular ligament and directly through the manubrium. For each 1 cm. increase in the circumference of the chest the capacity increases by about 200 ml. The twelfth rib is fixed by the quadratus lumborum so that the diaphragm is able to exert a more powerful downward thrust on the abdominal viscera. In addition the erector spinae come into action and the concavity of the thoracic vertebral column is diminished which results in a slight increase in the width of the intercostal spaces and allows the ribs a greater range of movement. The intrapulmonary pressure at the beginning of deep expiration may rise to 30 mm of mercury above atmospheric pressure

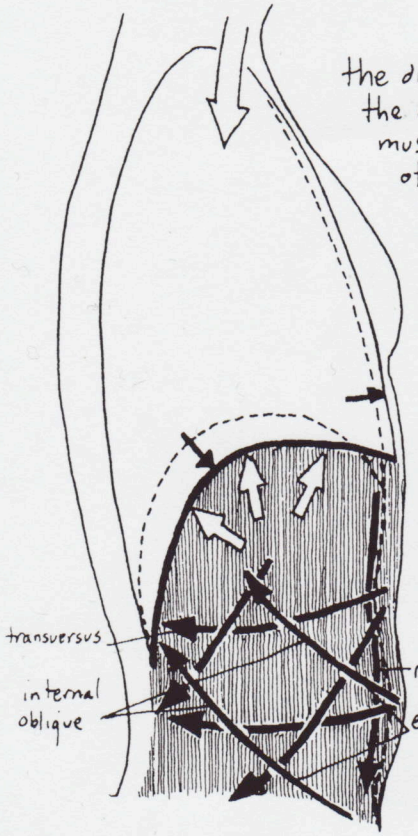
In forced respiration, as in breathing against resistance, further muscles are called into action. In forced inspiration the diaphragm contracts maximally, the action of the erector spinae is increased and muscles connecting the upper limb to the trunk may show activity. In forced expiration additional expulsive factors are provided by the strong contraction of the muscles of the abdominal wall, particularly the obliques and transversus, and by latissimus dorsi which contracts suddenly and energetically with such efforts as sneezing and coughing. The muscles of the abdominal wall raise the intra-abdominal pressure, forcing the relaxing diaphragm upwards and drawing the lower ribs downwards and medially.

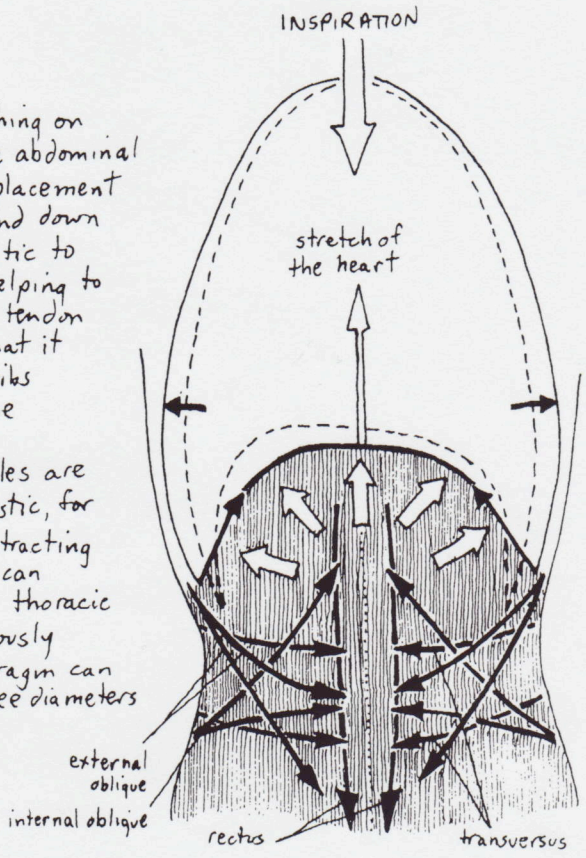
The range and character of the movements of the thorax exhibit very striking individual variations, which may be dependent on the conformation of the thoracic skeleton, on habit or on other factors, for breathing and its apparatus is so interconnected with the rest of the body and its activities that disturbances anywhere are almost certain to affect it.

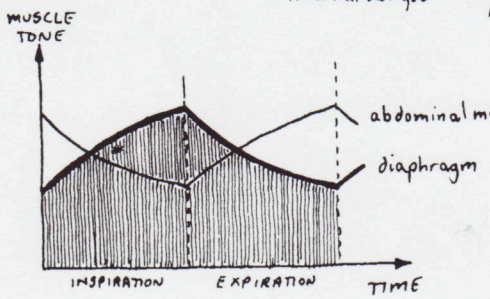
This extreme variability must be borne in mind when movements are being analysed in any particular individual.

INSPIRATION

the diaphragm contracts pushing on the abdominal visceral, the abdominal muscles help to resist displacement of the viscera forwards and down thus becoming synergistic to the diaphragm by helping to stabilize the central tendon of the diaphragm so that it can pull the lower ribs up and out. Thus the diaphragm and the abdominal muscles are synergistic/antagonistic, for in expiration the contracting abdominal muscles can reduce the three thoracic diameters simultaneously just as the diaphragm can increase the three diameters in inspiration.

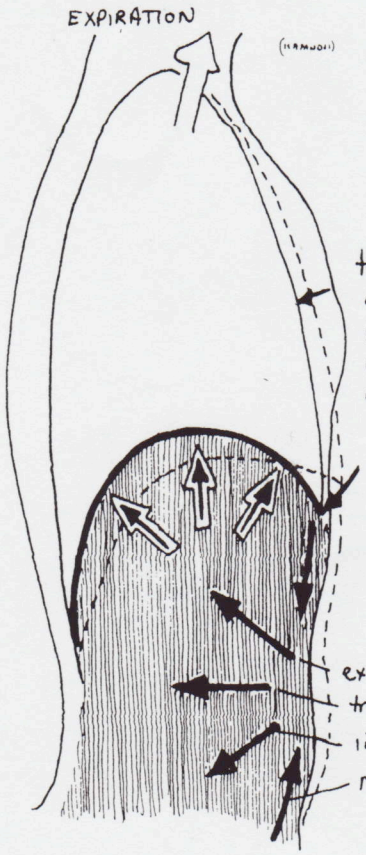




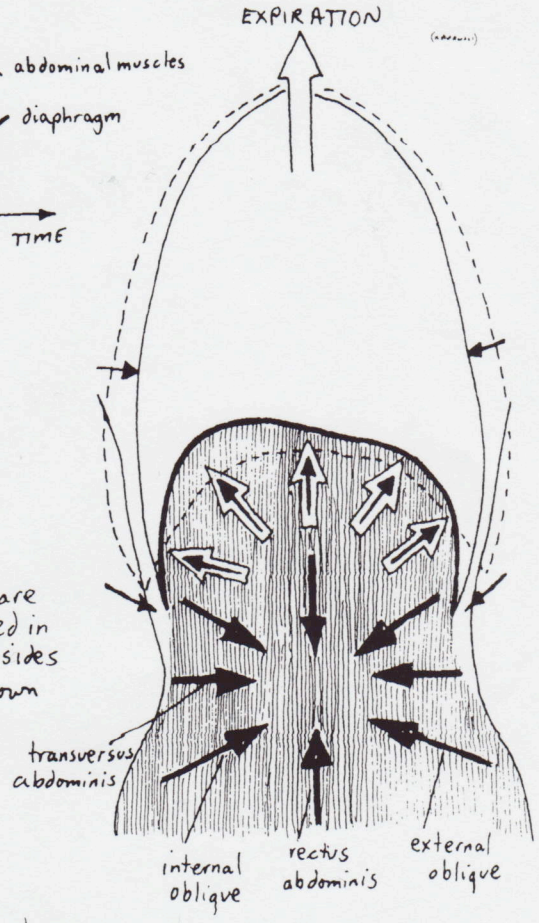


EXPIRATION

the abdominal muscles contract, as the diaphragm relaxes, raising the abdominal pressure and pushing the diaphragm up and the lower ribs are pulled down and back



ribs are pulled in at the sides and down



The activity of both sets of muscles, the diaphragm and the abdominal muscles, varies reciprocally. Thus, during inspiration the tonus of the diaphragm increases while that of the abdominal muscles decreases, and vice versa during expiration. Hence there exists between these two muscle groups a floating equilibrium constantly shifting in both directions.