In contrast to the abdominal cavity, the thoracic cavity changes both shape and volume; it behaves as a flexible gas-filled container, similar to an accordion bellows. When you squeeze an accordion, you create a reduction in the volume of the bellows and air is forced out. When you pull the bellows open, its volume increases and air is pulled in (figure 1.6). This occurs because the accordion is compressible and expandable, as is air. The same is true of the thoracic cavity, which, unlike the abdominal cavity and its contents, can change its shape and volume in breathing.

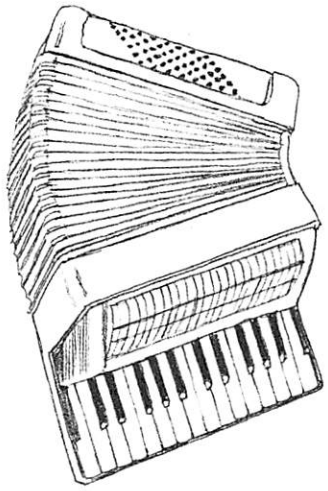


Figure 1.6 The accordion changes shape and volume.

Let's now imagine the thoracic and abdominal cavities as an accordion stacked on top of a water balloon. This image gives a sense of the relationship of the two cavities in breathing; movement in one will necessarily result in movement in the other. Recall that during an inhalation (the shape change permitting air to be pushed into the lungs by the planet's atmospheric pressure), the thoracic cavity expands its volume. This pushes downward on the abdominal cavity, which changes shape as a result of the pressure from above.

By defining breathing as shape change, it becomes very easy to understand what constitutes effective or obstructed breath—it is simply the ability or inability of the structures that define and surround the body's cavities to change shape.

The Universe Breathes Us

Volume and pressure are inversely related; when volume increases, pressure decreases, and when volume decreases, pressure increases. Because air always flows toward areas of lower pressure, increasing the volume inside the thoracic cavity will decrease pressure and cause air to flow into it. This is an inhalation.

It is important to note that in spite of how it feels when you inhale, you do not actually pull air into the body. On the contrary, air is pushed into the body by the atmospheric pressure (14.7 pounds per square inch, or 1.03 kg/cm^2) that always surrounds you. This means that the actual force that gets air into the lungs is outside of the body. The energy expended in breathing produces a shape change that lowers the pressure in the chest cavity and permits the air to be pushed into the body by the weight of the planet's atmosphere. In other words, you create the space, and the universe fills it.

During relaxed, quiet breathing such as while sleeping, an exhalation is a passive reversal of this process. The thoracic cavity and lung tissue—which have been stretched open during the inhalation—spring back to their initial volume, pushing the air out and returning them to their previous shapes. This is referred to as a *passive recoil*. Any reduction in the elasticity of these tissues results in a reduction of the body's ability to exhale passively, leading to a host of respiratory problems such as emphysema and pulmonary fibrosis, which greatly compromise the elasticity of the lung tissue.

In breathing patterns that involve active exhaling, such as blowing out candles, speaking, singing, and performing various yoga exercises, the musculature surrounding the two cavities contracts in such a way that the abdominal cavity is pushed upward into the thoracic cavity or the thoracic cavity is pushed downward onto the abdominal cavity, or any combination of the two.

Three-Dimensional Shape Changes of Breathing

Because the lungs occupy a three-dimensional space in the thoracic cavity, when this space changes shape to cause air movement, it changes shape three-dimensionally. Specifically, an inhalation involves the chest cavity increasing its volume from top to bottom, from side to side, and from front to back, and an exhalation involves a reduction of volume in those three dimensions (see figure 1.7).

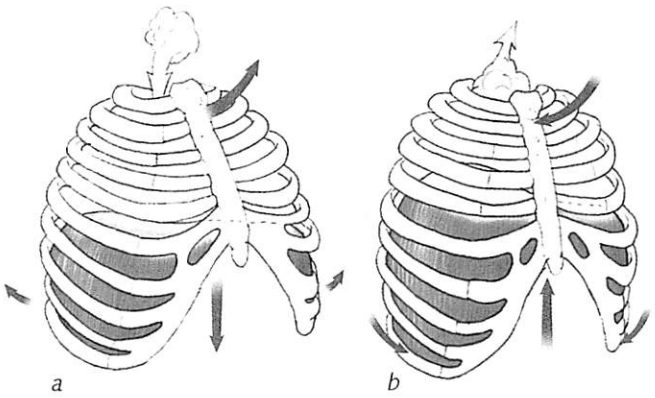


Figure 1.7 Three-dimensional thoracic shape changes of *(a)* inhalation and *(b)* exhalation.

Because thoracic shape change is inextricably linked to abdominal shape change, you can also say that the abdominal cavity also changes shape (not volume) in three dimensions—it can be squeezed from top to bottom, from side to side, or from front to back (see figure 1.8). In a living, breathing body, thoracic shape change cannot occur without abdominal shape change. That is why the condition of the abdominal region has such an influence on the quality of our breathing and why the quality of our breathing has a powerful effect on the health of our abdominal organs.

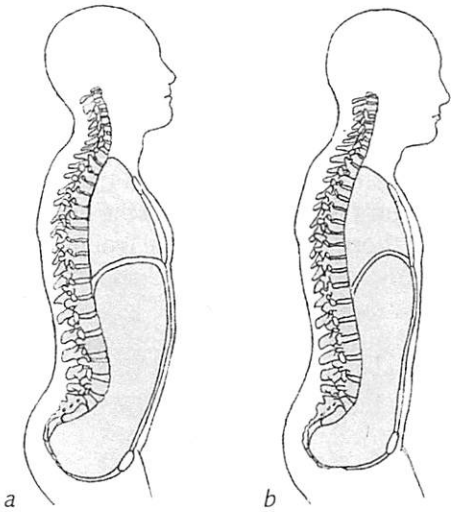


Figure 1.8 Changes in abdominal shape during breathing: *(a)* inhalation as spinal extension and *(b)* exhalation as spinal flexion.

EXPANDED DEFINITION OF BREATHING

Based on the information we have so far, here's an expanded definition of breathing:

> *Breathing, the process of taking air into and expelling it from the lungs, is caused by a three-dimensional shape change in the thoracic and abdominal cavities.*

Defining breathing in this manner explains not only what it is but also how it is done. As a thought experiment, try this: Substitute the term *shape change* for the word *breathing* whenever discussing the breath. For example, "I just had a really good breath" really means "I just had a really good shape change." More important, "I'm having difficulty breathing" really means "I'm having trouble changing the shape of my cavities." This concept has profound therapeutic implications, because it tells us where to start looking for the root causes of breath and postural issues, and it can eventually lead us to examine the supporting, shape-changing structure that occupies the back of the body's two primary cavities—the spine, which is discussed in chapter 2.

A key observation that has been made in yogic teachings is that spinal movements are an intrinsic component of the shape-changing activity of the cavities (breathing). This is why such a huge component of yoga practice involves coordinating the movements of the spine with the process of inhaling and exhaling.

There's a reason why students are instructed to inhale during spinal extension and exhale during spinal flexion. Fundamentally, the spinal shape change of extension is an inhale and the spinal shape change of spinal flexion is an exhale.

THE DIAPHRAGM'S ROLE IN BREATHING

A single muscle, the diaphragm, is capable of producing—on its own—all of the three-dimensional movements of breath. This is why just about every anatomy book describes the diaphragm as the principal muscle of breathing. Let's add the diaphragm to our shape-change definition of breathing to begin our exploration of this remarkable muscle:

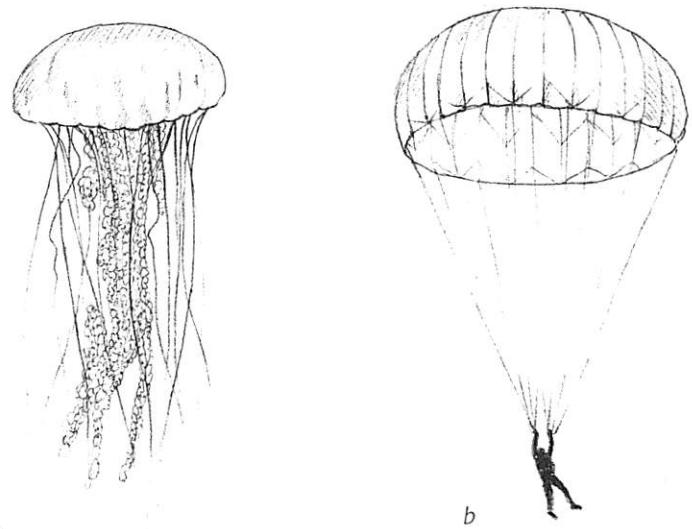
The diaphragm is the principal muscle that causes three-dimensional shape change in the thoracic and abdominal cavities.

To understand how the diaphragm causes this shape change, it is important to examine its shape and location in the body, where it is attached and what is attached to it, its action, and its relationship to the other muscles of breathing.

Shape and Location

The deeply domed shape of the diaphragm has evoked many images. Two of the most common are a jellyfish and a parachute (figure 1.9). It is important to note that the diaphragm's shape is created by the organs it encloses and supports. Deprived of its relationship with those organs, its dome would collapse, much like a stocking cap without a head in it. It is also evident that the diaphragm has an asymmetrical double-dome shape; the right dome rises higher than the left. The liver pushes up from below the right dome, and the heart pushes down from above the left dome (see figure 1.10 on page 9).

The diaphragm divides the torso into the thoracic and abdominal cavities. It is the floor of the thoracic cavity and the roof of the abdominal cavity. Its structure extends through



a b

Figure 1.9 The shape of the diaphragm reminds many people of *(a)* a jellyfish or *(b)* a parachute.

Vocal Diaphragm

The gateway to the respiratory passages is the glottis, shown in figure 1.21, which is not a structure but a space between the vocal folds (cords).

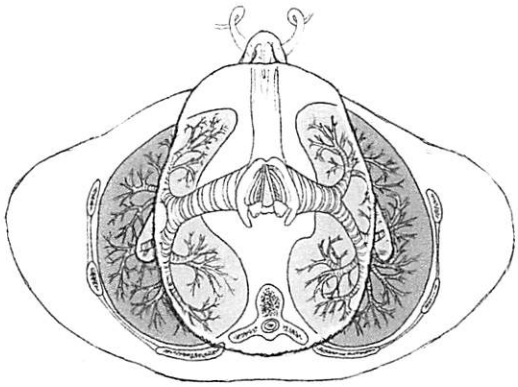


Figure 1.21 The pathway of air into and out of the lungs, showing the location of the vocal folds.

Yoga practitioners are accustomed to regulating this space in various ways based on what they are doing with their breath, voice, and posture. When at rest, the muscles that control the vocal cords can be relaxed so that the glottis is being neither restricted nor enlarged (see figure 1.22*a*). This occurs in sleep and in the more restful, restorative practices in yoga.

When doing breathing exercises that involve deep, rapid movements of breath, such as kapalabhati or bhastrika (*bhastra* meaning bellows) the muscles that pull the vocal folds apart (abduction) contract to create a larger passage for the air movements (see figure 1.22*b*).

When chanting, singing, or speaking, the vocal folds are drawn together (adduction), which causes them to vibrate as the exhaled air is forced across them. This vibration is termed *phonation* (see figure 1.22*c*).

When the exercises call for long, deep, slow breaths, the glottis can be partially closed, with only a small opening at the back of the cords (see figure 1.22*d*). This is the same

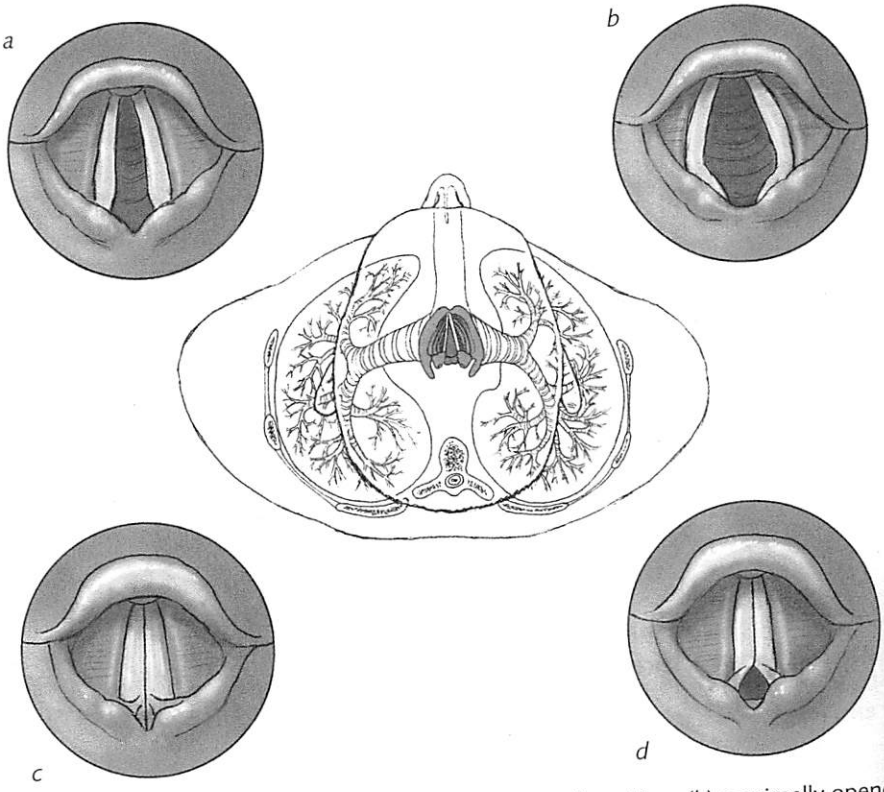


Figure 1.22 Position and location of vocal folds: *(a)* relaxed position, *(b)* maximally opened for forced respiration, *(c)* closed for speaking (phonation), *(d)* slightly opened for whispered speech (or *ujjayi*).

action that creates whispered speech; in yoga it's known as *ujjayi*, the victorious breath (*ud* meaning to flow out and *jaya* meaning victory or triumph). This action also creates more postural support in the body, as we will explore in the next section.

The Bandhas

All three diaphragms (pelvic, respiratory, and vocal) come together with ujjayi in yoga movements that are coordinated with inhaling and exhaling. In addition to giving more length and texture to the breath, the valve of ujjayi creates a kind of back pressure throughout the abdominal and thoracic cavities. This pressure can protect the spine during the long, slow flexion and extension movements that occur in the breath-synchronized flowing practice of *vinyasa* (arrangement or placement), such as during sun salutations. In yogic terms, these coordinated actions of the diaphragms (bandhas) create more sthira (stability) in the body, protecting it from injury by redistributing mechanical stress.

Figure 1.23 shows a mechanical analysis of the body entering into a forward bend from two perspectives. In figure 1.23*a*, we see the torso moving without breath support. Because the breathing musculature surrounding the cavities is not engaged, there is no single center of gravity to the shape, and a partial center of gravity (B) is acting upon the long arm of a lever (C), of which the fulcrum point (A) is at the vulnerable disc of the lumbosacral junction. The weight of the torso is being controlled by the posterior musculature, which compressively acts on the short end of the lever (D). The body instinctively resents this extremely poor leverage, and that's why we tend to hold our breath in situations like this to avoid damaging our spinal structures.

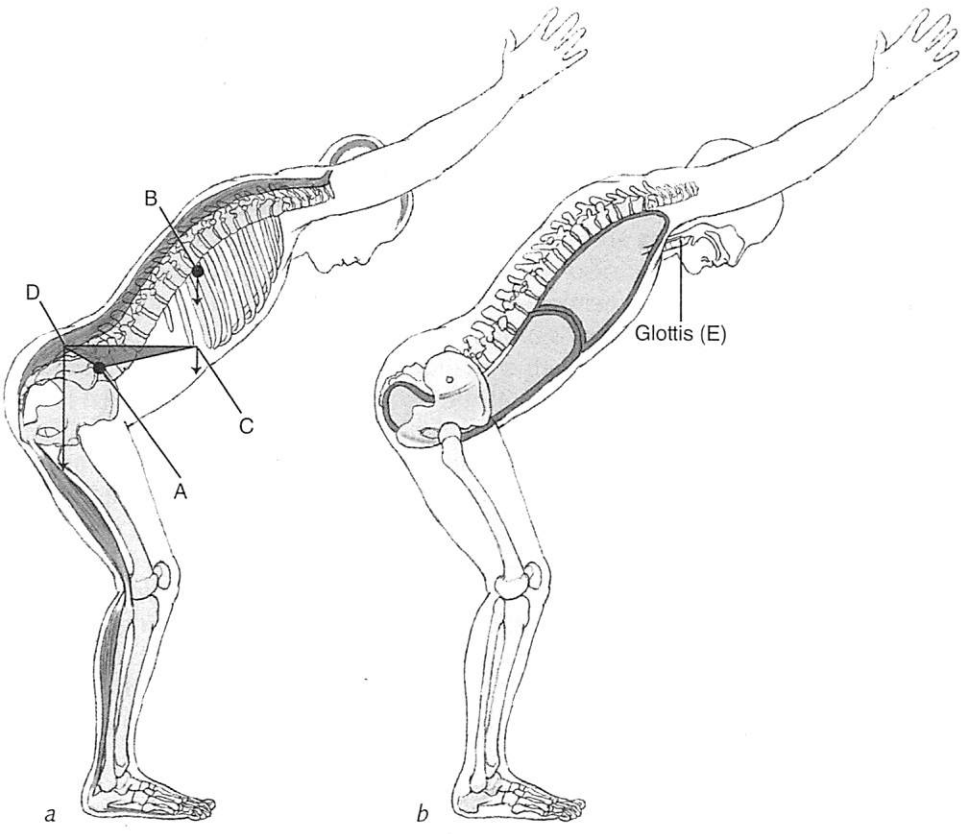


Figure 1.23 Supporting a movement *(a)* without the breath and *(b)* with the breath.