YOGA ANATOMY

Leslie Kaminoff

Asana Analysis by
Amy Matthews

Illustrated by
Sharon Ellis

Human Kinetics

CHAPTER 1

DYNAMICS OF BREATHING

The most basic unit of life, the cell, can teach you an enormous amount about yoga. In fact, the most essential yogic concepts can be derived from observing the cell's form and function. This chapter explores breath anatomy from a yogic perspective, using the cell as a starting point.

Yoga Lessons From a Cell

Cells are the smallest building blocks of life, from single-celled plants to multitrillion-celled animals. The human body, which is made up of roughly 100 trillion cells, begins as a single, newly fertilized cell.

A cell consists of three parts: the cell membrane, the nucleus, and the cytoplasm. The membrane separates the cell's external environment, which contains nutrients that the cell requires, from its internal environment, which consists of the cytoplasm and the nucleus. Nutrients have to get through the membrane, and once inside, the cell metabolizes these nutrients and turns them into the energy that fuels its life functions. As a result of this metabolic activity, waste gets generated that must somehow get back out through the membrane. Any impairment in the membrane's ability to let nutrients in or waste out will result in the death of the cell via starvation or toxicity. This observation that living things take in nutrients provides a good basis for understanding the term *prana*, which refers to what nourishes a living thing. *Prana* refers not only to what is brought in as nourishment but also to the *action* that brings it in.[1]

Of course, there has to be a complementary force. The yogic concept that complements prana is *apana*, which refers to what is eliminated by a living thing as well as the action of elimination.[2] These two fundamental yogic terms—prana and apana—describe the essential activities of life.

Successful function, of course, expresses itself in a particular form. Certain conditions have to exist in a cell for nutrition (prana) to enter and waste (apana) to exit. The membrane's structure has to allow things to pass in and out of it—it has to be permeable (see figure 1.1). It can't be so permeable, however, that the cell wall loses its integrity; otherwise, the cell will either explode from the pressures within or implode from the pressures outside.

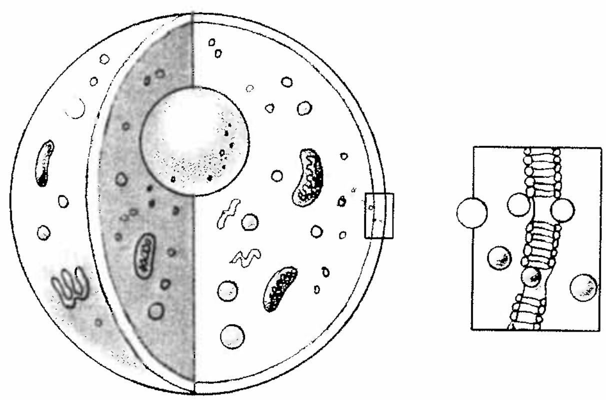

Figure 1.1 The cell's membrane must balance containment (stability) with permeability.

[1] The Sanskrit word *prana* is derived from *pra*, a prepositional prefix meaning "before," and *an*, a verb meaning "to breathe," "to blow," and "to live." Here, *prana* is not being capitalized, because it refers to the functional life processes of a single entity. The capitalized *Prana* is a more universal term that is used to designate the manifestation of all creative life force.

[2] The Sanskrit word *apana* is derived from *apa*, which means "away," "off," and "down," and *an*, which means "to blow," "to breathe," and "to live."

In the cell (and all living things, for that matter), the principle that balances permeability is stability. The yogic terms that reflect these polarities are *sthira*[3] and *sukha*.[4] All successful living things must balance containment and permeability, rigidity and plasticity, persistence and adaptability, space and boundaries.[5]

You have seen that observing the cell, the most basic unit of life, illuminates the most basic concepts in yoga: prana/apana and sthira/sukha. Next is an examination of the structure and function of the breath using these concepts as a guide.

Prana and Apana

The body's pathways for nutrients and waste are not as simple as those of a cell, but they are not so complex that you can't grasp the concepts as easily.

Figure 1.2 shows a simplified version of the nutritional and waste pathways. It shows how the human system is open at the top and at the bottom. You take in prana, nourishment, in solid and liquid form at the top of the system: It enters the alimentary canal, goes through the digestive process, and after a lot of twists and turns, the resulting waste moves down and out. It has to go down to get out because the exit is at the bottom. So, the force of apana, when it's acting on solid and liquid waste, has to move down to get out.

You also take in prana in gaseous form: The breath, like solid and liquid nutrition, enters at the top. But the inhaled air remains above the diaphragm in the lungs (see figure 1.3), where it exchanges gases with the capillaries at the alveoli. The waste gases in the lungs need to get out—but they need to get back out the same way they came in. This is why it is said that apana must be able to operate freely both upward and downward, depending on what type of waste it's acting on. That is also why any inability to reverse apana's downward push will result in an incomplete exhalation.

The ability to reverse apana's downward action is a very basic and useful skill that can be acquired through yoga training, but it is not something that most people are able to do right away. Pushing downward is the way that most people are accustomed to operating their apana because whenever there's anything within the body that needs to be disposed, humans tend to squeeze in and push down. That is why most beginning yoga students, when asked to exhale completely, will squeeze in and push down their breathing muscles as if they're urinating or defecating.

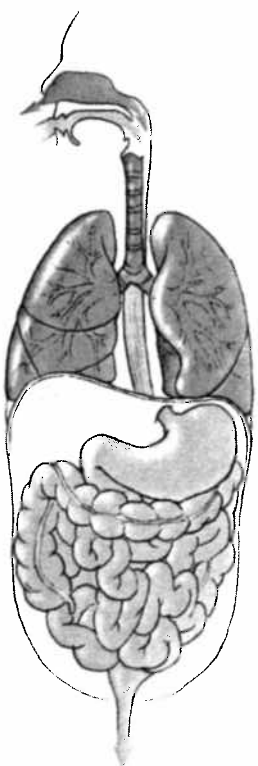

Figure 1.2 Solid and liquid nutrition (blue) enter at the top of the system and exit as waste at the bottom. Gaseous nutrition and waste (red) enter and exit at the top.

[3] The Sanskrit word *sthira* means "firm," "hard," "solid," "compact," "strong," "unfluctuating," "durable," "lasting," and "permanent." English words such as *stay*, *stand*, *stable*, and *steady* are likely derived from the Indo-European root that gave rise to the Sanskrit term.

[4] The Sanskrit word *sukha* originally meant "having a good axle hole," implying a space at the center that allows function; it also means "easy," "pleasant," "agreeable," "gentle," and "mild."

[5] Successful man-made structures also exhibit a balance of sthira and sukha; for example, a colander's holes that are large enough to let out liquid, but small enough to prevent pasta from falling through, or a suspension bridge that's flexible enough to survive wind and earthquake, but stable enough to support its load-bearing surfaces.

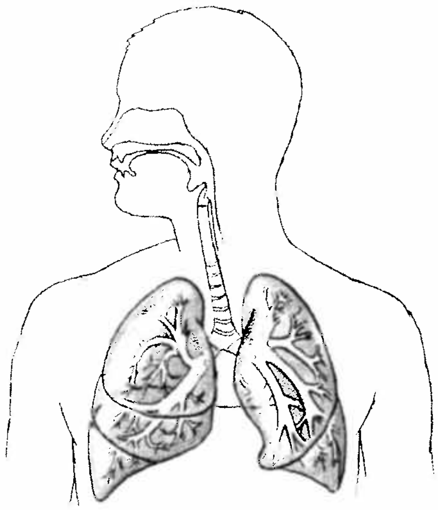

Figure 1.3 The pathway that air takes into and out of the body.

Sukha and Dukha

The pathways must be clear of obstructing forces in order for prana and apana to have a healthy relationship. In yogic language, this region must be in a state of *sukha*, which literally translates as "good space." "Bad space" is referred to as *dukha*, which is commonly translated as "suffering."[6]

This model points to the fundamental methodology of all classical yoga practice, which attends to the blockages, or obstructions, in the system to improve function. The basic idea is that when you make more "good space," your pranic forces will flow freely and restore normal function. This is in contrast to any model that views the body as missing something essential, which has to be added from the outside. This is why it has been said that yoga therapy is 90 percent about waste removal.

Another practical way of applying this insight to the field of breath training is the observation: If you take care of the exhalation, the inhalation takes care of itself.

Breathing, Gravity, and Yoga

Keeping in the spirit of starting from the beginning, let's look at some of the things that happen at the very start of life.

In utero, oxygen is delivered through the umbilical cord. The mother does the breathing. There is no air and very little blood in the lungs when in utero because the lungs are nonfunctional and mostly collapsed. The circulatory system is largely reversed, with oxygen-rich blood flowing through the veins and oxygen-depleted blood flowing through the arteries. Humans even have blood flowing through vessels that won't exist after birth, because they will seal off and become ligaments.

Being born means being severed from the umbilical cord—the lifeline that sustained you for nine months. Suddenly, and for the first time, you need to engage in actions that will ensure continued survival. The very first of these actions declares your physical and physiological independence. *It is the first breath*, and it is the most important and forceful inhalation you will ever take in your life.

That first inhalation was the most important one because the initial inflation of the lungs causes essential changes to the entire circulatory system, which had previously been geared toward receiving oxygenated blood from the mother. The first breath causes blood to surge into the lungs, the right and left sides of the heart to separate into two pumps, and the specialized vessels of fetal circulation to shut down and seal off.

That first inhalation is the most forceful one you will ever take because it needs to overcome the initial surface tension of your previously collapsed and amniotic-fluid-filled lung

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[6] The Sanskrit word *sukha* is derived from *su* (meaning "good") and *kha* (meaning "space"). In this context (paired with dukha), it refers to a state of well-being, free of obstacles. Like the "good axle hole," a person needs to have "good space" at his or her center. The Sanskrit word *dukha* is derived from *dus* (meaning "bad") and *kha* (meaning "space"). It is generally translated as "suffering"; also, "uneasy," "uncomfortable," "unpleasant," and "difficult."

tissue. The force required (called negative inspiratory force) is three to four times greater than that of a normal inhalation.

Another first-time experience that occurs at the moment of birth is the weight of the body in space. Inside the womb, you're in a weightless, fluid-filled environment. Then, suddenly, your entire universe expands because you're out—you're free. Now, your body can move freely in space, your limbs and head can move freely in relation to your body, and you must be supported in gravity. Because adults are perfectly willing to swaddle babies and move them from place to place, stability and mobility may not seem to be much of an issue so early in life, but they are. The fact is, right away you have to start *doing* something—you have to find nourishment, which involves the complex action of simultaneously breathing, sucking, and swallowing. All of the muscles involved in this intricate act of survival also create your first postural skill—supporting the weight of the head. This necessarily involves the coordinated action of many muscles, and—as with all postural skills—a balancing act between mobilization and stabilization. Postural development continues from the head downward, until you begin walking (after about a year), culminating with the completion of your lumbar curve (at about 10 years of age).

To summarize, the moment you're born, you're confronted by two forces that were not present in utero: breath and gravity. To thrive, you need to reconcile those forces for as long as you draw breath on this planet. The practice of yoga can be seen as a way of consciously exploring the relationship between breath and posture, so it's clear that yoga can help you to deal with this fundamental challenge.

To use the language of yoga, life on this planet requires an integrated relationship between breath (prana/apana) and posture (sthira/sukha). When things go wrong with one, by definition they go wrong with the other.

The prana/apana concept is explored with a focus on the breathing mechanism. Chapter 2 covers the sthira/sukha concept by focusing on the spine. The rest of the book examines how the breath and spine come together in the practice of yoga postures.

Breathing Defined

Breathing is the process of taking air into and expelling it from the lungs. This is a good place to start, but let's define the "process" being referred to. Breathing—the passage of air into and out of the lungs—is movement, one of the fundamental activities of living things. Specifically, breathing involves movement in two cavities.

Movement in Two Cavities

The simplified illustration of the human body in figure 1.4 shows that the torso consists of two cavities, the thoracic and the abdominal. These cavities share some properties, and they have important distinctions as well. Both contain vital organs: The thoracic contains the heart and lungs, and the abdominal contains the stomach, liver, gall bladder, spleen, pancreas, small and large intestines, kidneys, and bladder, among others. Both cavities are bounded posteriorly by the spine. Both open at one end to the external environment—the thoracic at the top, and the abdominal at the bottom. Both share an important structure, the diaphragm (it forms the roof of the abdominal cavity and the floor of the thoracic cavity).

Another important shared property of the two cavities is that they are mobile—they change shape. It is this shape-changing ability that is most relevant to breathing, because without this movement, the body cannot breathe at all. Although both the abdominal and thoracic cavities change shape, there is an important structural difference in how they do so.

The abdominal cavity changes shape like a flexible, fluid-filled structure such as a water balloon. When you squeeze one end of a water balloon, the other end bulges. That is

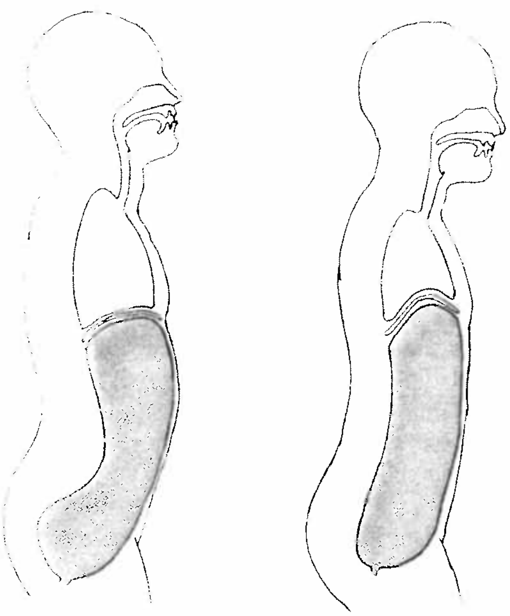

Figure 1.4 Breathing is thoracoabdominal shape change. Inhalation on left, exhalation on right.

because water is noncompressible. Your hand's action only moves the fixed volume of water from one end of the flexible container to the other. The same principle applies when the abdominal cavity is compressed by the movements of breathing; a squeeze in one region produces a bulge in another. That is because in the context of breathing, the abdominal cavity changes shape, but not volume.

In the context of life processes other than breathing, the abdominal cavity *does* change volume. If you drink a gallon of liquid or eat a big meal, the overall volume of the abdominal cavity will increase as a result of expanded abdominal organs (stomach, intestines, bladder). Any increase of volume in the abdominal cavity will produce a corresponding decrease in the volume of the thoracic cavity. That is why it's harder to breathe after a big meal, before a big bowel movement, or when pregnant.

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 the air is pulled in. This is because the accordion is compressible and expandable. The same is true of the thoracic cavity, which, unlike the abdominal cavity and its contents, can change its shape *and* volume.

Volume and Pressure

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 (think of an accordion) will decrease pressure and cause air to flow into it. This is an inhalation.

It is interesting to note that in spite of how it feels when you inhale, you are not *pulling* air into the body. On the contrary, air is pushed into the body by atmospheric pressure that always surrounds you. The actual force that gets air into the lungs is outside of the body. The energy you expend in breathing produces a shape change that lowers the pressure in your chest cavity and permits the air to be pushed into the body by the weight of the planet's atmosphere.

Let's now imagine the thoracic and abdominal cavities as an accordion stacked on top of a water balloon. This illustration 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.

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 the thoracic cavity to its previous shape. This is referred to as a *passive recoil*. Any reduction in the elasticity of these tissues will result in a reduction of the body's ability to exhale passively—leading to a host of respiratory problems.

In breathing patterns that involve active exhaling (such as blowing out candles, speaking, and singing, as well as 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 into 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 1.5).

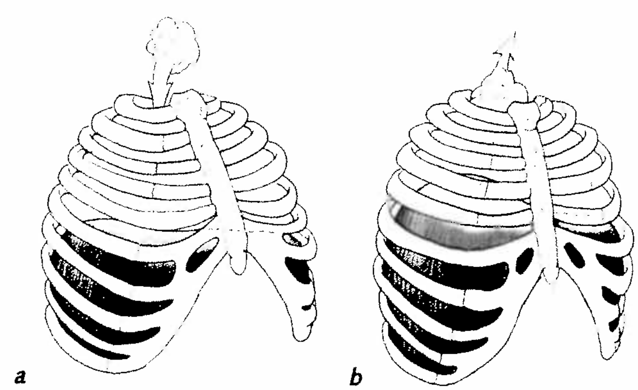

Figure 1.5 Three-dimensional thoracic shape changes of *(a)* inhalation and *(b)* exhalation.

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 pushed or pulled from top to bottom, from side to side, or from front to back (see figure 1.6). In a living, breathing body, thoracic shape change cannot happen without abdominal shape change. That is why the condition of the abdominal region has such an influence on the quality of your breathing and why the quality of your breathing has a powerful effect on the health of your abdominal organs.

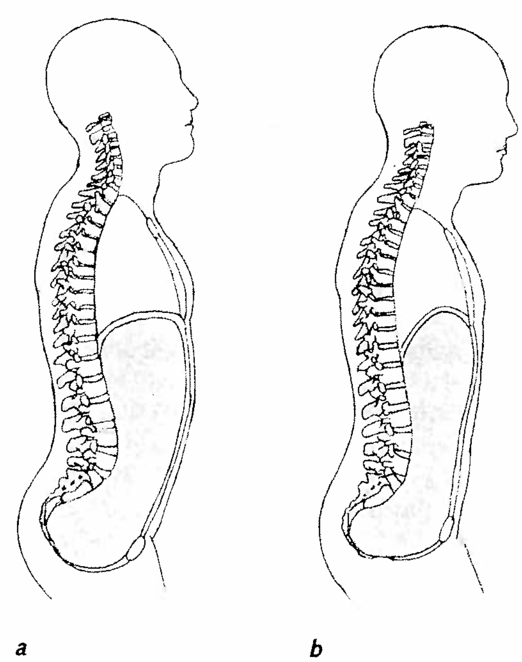

Figure 1.6 Changes in abdominal shape during breathing: *(a)* Inhalation = spinal extension; *(b)* exhalation = spinal flexion.

Expanded Definition of Breathing

Based on the information you 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 changing of shape in the thoracic and abdominal cavities.

Defining breathing in this manner explains not only what it is but also how it is done. This has profound implications for yoga practice, because it can lead you to examine the supporting, shape-changing structure that occupies the back of the body's two primary cavities—the spine, which is covered in chapter 2.

To understand how a single muscle, the diaphragm, is capable of producing all this movement, you now examine it in detail.

Diaphragm's Role in Breathing

Just about every anatomy book describes the diaphragm as the principal muscle of breathing. Add the diaphragm to the shape-change definition of breathing to begin your 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, you will examine its shape and location in the body, where it's attached, and what is attached to it, as well as its action and relationship to the other muscles of breathing.

Shape and Location

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 wide section of the body—the uppermost part reaches the space between the third and fourth ribs, and its lowest fibers attach to the front of the third lumbar vertebra; "nipple to navel" is one way to describe it.

The deeply domed shape of the diaphragm has evoked many images. Some of the most common are a mushroom, a jellyfish, a parachute, and a helmet. It's important to note that the shape of the diaphragm 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, with the right dome rising higher than the left. This is because the liver pushes up from below the right dome, and the heart pushes down from above the left dome.

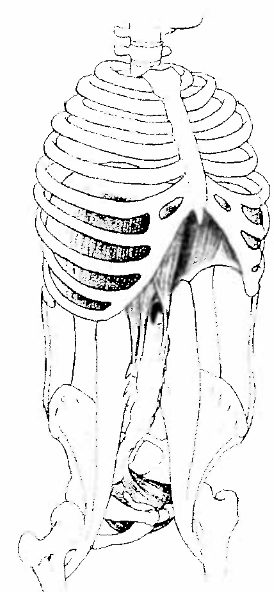

Figure 1.7 Origin and insertion of the diaphragm muscle.

Origin and Insertion

The lower edges of the diaphragm's circumference originate from three distinct regions: the bottom of the sternum, the base of the rib cage, and the front of the lower spine (see figure 1.7). These three regions form a continuous rim of attachment for the diaphragm. The only bony components of this rim are the back of the xiphoid process and the front surfaces of the first three lumbar vertebrae. The majority of the diaphragm (over 90 percent) originates on flexible tissue: the costal cartilage of ribs 6 through 10 and the arcuate ligaments, which bridge the span from the 10th rib's cartilage to the floating 11th and 12th ribs and from there to the spine.

All the muscular fibers of the diaphragm rise upward in the body from their origins. They eventually arrive at the flattened, horizontal top of the muscle, the central tendon, into which they insert. In essence, the diaphragm inserts into itself—its own central tendon which is fibrous noncontractile tissue.

Organic Connections

The central tendon of the diaphragm is a point of anchorage for the connective tissue that surrounds the thoracic and abdominal organs. The names of these important structures are easily remembered as the three Ps.

- *Pleura*, which surround the lungs
- *Pericardium*, which surrounds the heart
- *Peritoneum*, which surrounds the abdominal organs

Thus, it should be clear that the shape-changing activity of these cavities has a profound effect on the movements of the organs they contain. The diaphragm is the primary source of these movements, and the relationship of its healthy functioning to the well-being of the organs is anatomically evident.

Actions

It is important to remember that the muscular fibers of the diaphragm are oriented primarily along the vertical (up–down) axis of the body, and this is the direction of the muscular action of the muscle. Recall that the horizontal central tendon is noncontractile and can move only in response to the action of the muscular fibers, which insert into it (see figure 1.8).

As in any other muscle, the contracting fibers of the diaphragm pull its insertion and origin (the central tendon and the base of the rib cage) toward each other. This muscle action is the fundamental cause of the three-dimensional thoracoabdominal shape changes of breathing.

To understand this fact more deeply, the question of whether origin moves toward insertion, or insertion moves toward origin, needs to be clarified. As with all muscles, the type of movement the diaphragm produces will depend on which end of the muscle is stable and which is mobile. To use an example of another muscle, the psoas muscle can create hip flexion either by moving the leg toward the front of the spine (as in standing on one leg and flexing the other hip) or by moving the front of the spine toward the leg (as in sit-ups with the legs braced). In both cases, the psoas muscle is doing the same thing—contracting. What differs is which end of the muscle is stable and which is mobile.

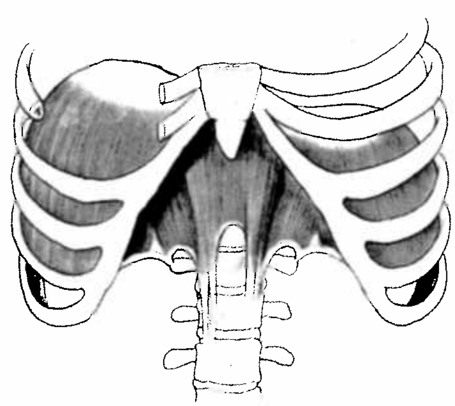

Figure 1.8 The muscle fibers of the diaphragm all run vertically from their origins to their insertion on the central tendon.

Just as you can think of the psoas as either a "leg mover" or a "trunk mover," you can think of the diaphragm as either a "belly bulger" or a "rib cage lifter" (see figure 1.9). The muscular action of the diaphragm is most often associated with a bulging[7] movement in the upper abdomen, which is commonly referred to as a "belly breath," but this is only the case if the diaphragm's origin (the base of the rib cage) is stable and its insertion (the central tendon) is mobile (see figure 1.10*a*).

If the central tendon is stabilized and the ribs are free to move, a diaphragmatic contraction will cause an expansion of the rib cage (see figure 1.10*b*). This is a "chest breath," which many people believe must be caused by the action of muscles other than the diaphragm. This mistaken idea can create a false dichotomy between diaphragmatic and "nondiaphragmatic" breathing. The unfortunate result of this error is that many people receiving breath training who exhibit chest movement (rather than belly movement) are told that they are not using the diaphragm, which is false. Except in cases of paralysis, the diaphragm is always used for breathing. The issue is whether it is being used efficiently.

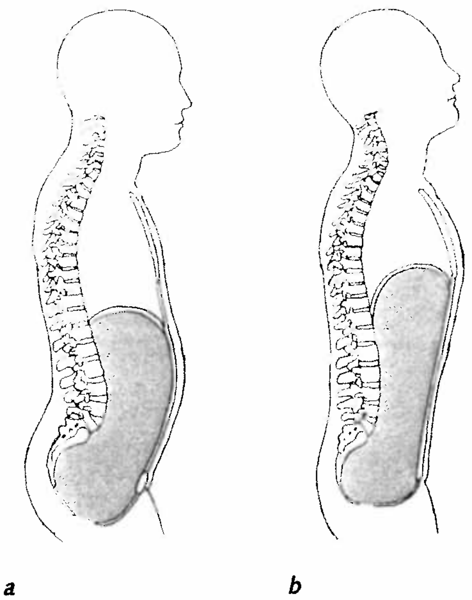

Figure 1.9 The diaphragm can be *(a)* a "belly bulger," during the belly inhalation, or *(b)* a "rib cage lifter," during the chest inhalation.

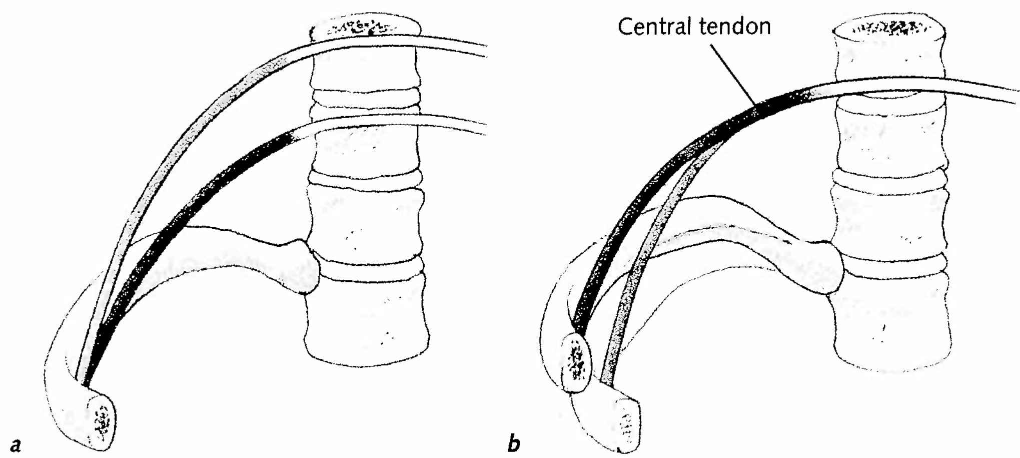

Figure 1.10 *(a)* With the rib stable and the abdominals relaxed, the diaphragm's contraction lowers the central tendon. *(b)* With the rib cage relaxed and the central tendon stabilized by abdominal action, the contracting diaphragm lifts the rib upward.

[7] Even though most teachers refer to this diaphragmatic action as an "expansion" of the abdomen, this is incorrect. In the context of breathing, the abdominal cavity does not change volume—only shape; therefore it is more accurate to refer to this movement as a "bulging" of the upper abdomen.

If it were possible to release all of the diaphragm's stabilizing muscles and allow its ori and insertion to freely move toward each other, both the chest and abdomen would mc simultaneously. This rarely occurs because the need to stabilize the body's mass in grav will cause many of the respiratory stabilizing muscles (which are also postural muscles) remain active through all phases of breathing.

Engine of Three-Dimensional Shape Change

The diaphragm is the prime mover of the thoracic and abdominal cavities. The speci patterns that arise in yoga asana practice or breathing exercises, however, result from t action of muscles other than the diaphragm that can change the shape of the caviti These are called *accessory muscles*. The analogy of a car and its engine is very useful explaining this principle.

The engine is the prime mover of the car. All the movements associated with a ca operation (including the electrical) are generated in the engine. In the same manner, t three-dimensional, thoracoabdominal shape change of breathing is primarily generated the diaphragm.

When you drive, the only direct control you exert over the function of the engine is tl speed of its spinning. You push the gas pedal to make the engine spin faster, and you relea the pedal to make it spin slower. Similarly, the only direct volitional control you have ov the diaphragm is its timing.

You don't steer your car with its engine. To control the power of the engine and gui it in a particular direction, you need the mechanisms of the transmission, brakes, steerin and suspension. In the same way, you don't "steer" your breathing with the diaphragm. control the power of the breath, and guide it into specific patterns, you need the assistan of the accessory muscles.

From the standpoint of this engine analogy, the whole notion of "diaphragmatic training as a way to improve breath function is flawed. After all, you don't become a better driv by learning only how to work the gas pedal. Most of the skills you acquire in driver trainir have to do with getting the acceleration of the car to coordinate with steering, braking, ar shifting gears. In a similar way, breath training is really "accessory muscle training." Onc all the other musculature of the body is coordinated and integrated with the action of th diaphragm, breathing will be efficient and effective.

Additionally, the notion that that diaphragmatic action is limited to abdominal bulgin (belly breathing) is as inaccurate as asserting that a car's engine is only capable of makin it go forward—and that some other source of power must govern reverse movement. Ju as this automotive error is linked to not understanding the relationship of the car's engin to its transmission, the breathing error results from not understanding the relationship c the diaphragm to the accessory muscles.

Moreover, equating belly movement with proper breathing and chest movement wit improper breathing is just as silly as stating that a car is best served by only driving forwar at all times. Without the ability to reverse its movements, a car would eventually end u someplace it couldn't get out of.

Accessory Muscles of Respiration

Although there is universal agreement that the diaphragm is the principal muscle of breath ing, there are various, sometimes conflicting ways of categorizing the other muscles tha participate in breathing. Using the definition of breathing as thoracoabdominal shape change you can define *any* muscle other than the diaphragm that can cause a shape change in th cavities as accessory (see figures 1.11 and 1.12 for example). It's irrelevant whether th shape change leads to an increase or a decrease of thoracic volume (inhalation or exhala tion), because both sets of muscles can be active during any phase of breathing. An example would be the analysis of a belly breath or a chest breath.

In the belly breath, the costal circumference (origin) of the diaphragm is stabilized by the muscles that pull the rib cage downward: the internal intercostals, the transversus thoracis, and others (see figures 1.13 to 1.16). These muscles are universally classified as "exhaling muscles," but here they actively participate in shaping an inhalation. In the chest breath, the central tendon (insertion) of the diaphragm is stabilized by the abdominal muscles, also regarded as "exhaling muscles," but in this case, they are clearly acting to produce a pattern of inhaling. It should be noted that in both of these cases, one region of accessory muscle has to be relaxed while the other is active. In the belly breath, the abdominal wall releases, and in the chest breath, the rib cage depressors have to let go.

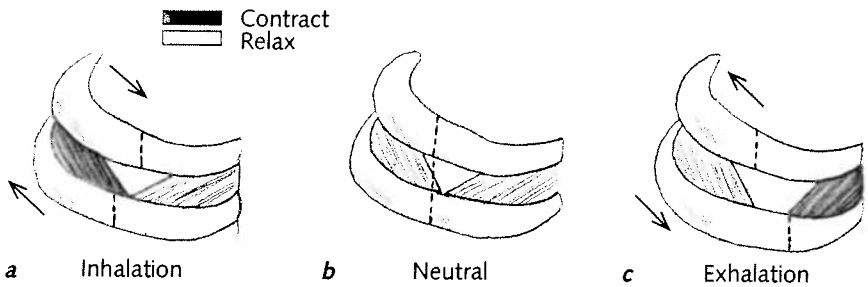

Figure 1.11 The intercostal muscles assist the sliding action of the ribs during respiration. During inhalation *(a)*, the external intercostals contract, and the internal intercostals relax. During exhalation *(c)*, the opposite occurs.

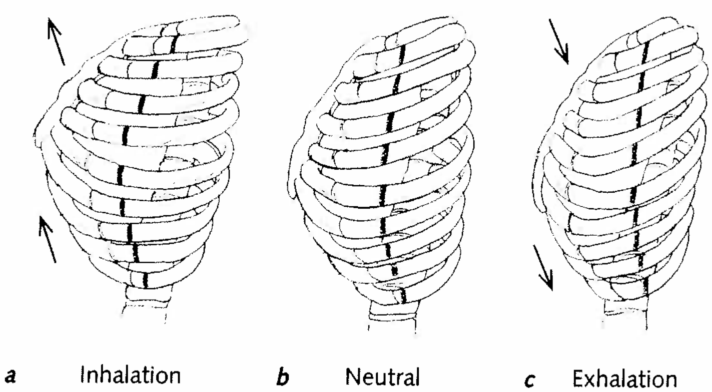

Figure 1.12 Contrary to appearances, the intercostal spaces remain constant during respiratory movements. Rather, the ribs slide in relation to each other—as indicated by the misaligning of the red line.

Abdominal and Thoracic Accessory Muscles

The abdominal cavity and its musculature can be imagined as a water balloon surrounded on all sides by elastic fibers running in all directions. The shortening and lengthening of these fibers in coordination with the contractions of the diaphragm produce the infinitely variable shape changes associated with respiration. As the tone of the diaphragm increases (inhalation), the tone of some abdominal muscles must decrease to allow the diaphragm to move. If you contract all your abdominal muscles at once and try to inhale, you'll notice that it's quite difficult because you've limited the ability of your abdomen to change shape.

The abdominal group doesn't affect breathing only by limiting or permitting shape chang in the abdominal cavity. Because they also attach directly to the rib cage, the abdomin muscles directly affect its ability to expand.

The abdominal muscles that have the most direct effect on breathing are the ones tha originate at the same place as the diaphragm, the transversus abdominis (see figure 1.13) This deepest layer of the abdominal wall arises from the costal cartilage at the base of th rib cage's inner surface. The fibers of the transversus are interdigitated (interwoven) at righ angles with those of the diaphragm, whose fibers ascend vertically, whereas those of th transversus run horizontally (see figure 1.14). This makes the transversus abdominis th direct antagonist to the diaphragm's action of expanding the rib cage. The same layer o horizontal fibers extends upward into the posterior thoracic wall as the tranversus thoracis a depressor of the sternum.

The other layers of the abdominal wall have similar counterparts in the thoracic cavity. The external obliques turn into the external intercostals, and the internal obliques turn into the internal intercostals (see figure 1.13). Of all these thoracoabdominal layers of muscle, only the external intercostals are capable of increasing thoracic volume. All the others produce a reduction of thoracic volume—either by depressing the rib cage or pushing upward on the central tendon of the diaphragm.

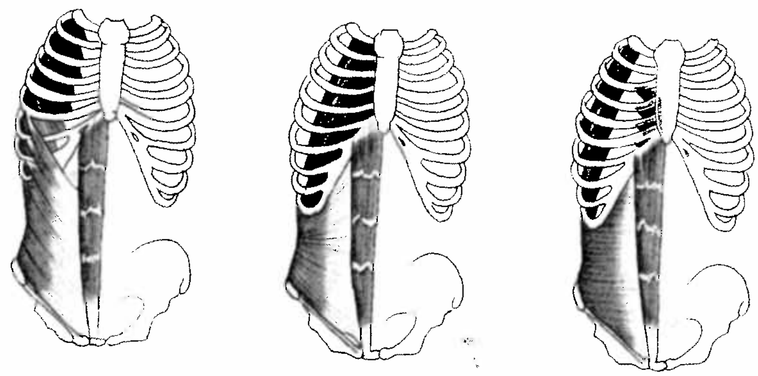

Figure 1.13 The continuity of the abdominal and intercostal layers shows how the external obliques turn into the external intercostals, internal obliques turn into the internal intercostals, and the transversus abdominis turns into the transversus thoracis and innermost intercostals.

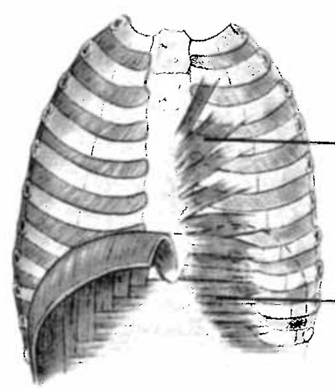

Figure 1.14 Posterior view of the chest wall, showing the interdigitated origins of the diaphragm and transversus abdominis forming perfect right angles with each other. This is clearly an agonist/antagonist, inhale/exhale muscle pairing that structurally underlies the yogic concepts of prana/apana.

Other Accessory Muscles

Chest, neck, and back muscles can expand the rib cage (see figures 1.15 and 1.16), but they are far more inefficient than the diaphragm and external intercostals at doing this. This inefficiency is the result of the fact that the location and attachment of these muscles do not provide enough leverage on the rib cage, and the usual role of these muscles is not respiration. They are primarily neck, shoulder girdle, and arm mobilizers—actions that require them to be stable proximally (toward the core of the body) and mobile distally (toward the periphery of the body). For these muscles to expand the rib cage, this relationship must be reversed—the distal insertions must be stabilized by yet more muscles so the proximal origins can be mobilized.

Considering the degree of muscular tension that accessory breathing entails, the net payoff in oxygenation makes it a poor energetic investment. That is why improved breathing is really a result of decreased tension in the accessory mechanism, which allows the diaphragm, with its shape-changing ability, to operate as efficiently as possible.

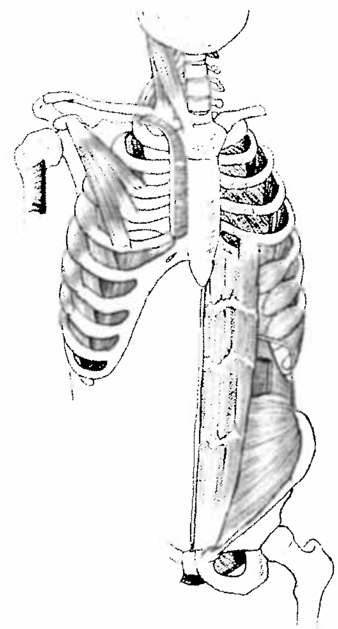

Figure 1.15 Some of the accessory muscles of respiration: Blue muscles act to reduce thoracic volume, while red muscles help to increase thoracic volume.

The Other Two Diaphragms

Along with the respiratory diaphragm, breathing involves the coordinated action of the pelvic and vocal diaphragms. Of particular interest to yoga practitioners is the action of mula bandha, which is a lifting action produced in the pelvic floor muscles (shown in figure 1.17, *a* and *b*) that also includes the lower fibers of the deep abdominal layers. Mula bandha is an action that moves apana upward and stabilizes the central tendon of the diaphragm. Inhaling while this bandha is active requires a release of the attachments of the upper abdominal wall, which permits the diaphragm to lift the base of the rib cage upward. This action is referred to as uddiyana bandha (*uddiya* means "flying upward").

It's important to note that the more superficial muscular fibers of the perineum need not be involved in mula bandha, because they contain the anal and urethral sphincters, which are associated with the downward movement of apana (elimination of solid and liquid waste), as shown in figure 1.18.

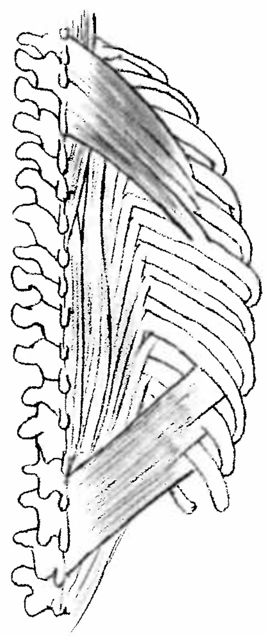

Figure 1.16 The serratus posterior muscles: superior (red) assist thoracic volume expansion, inferior (blue) assist thoracic volume reduction.

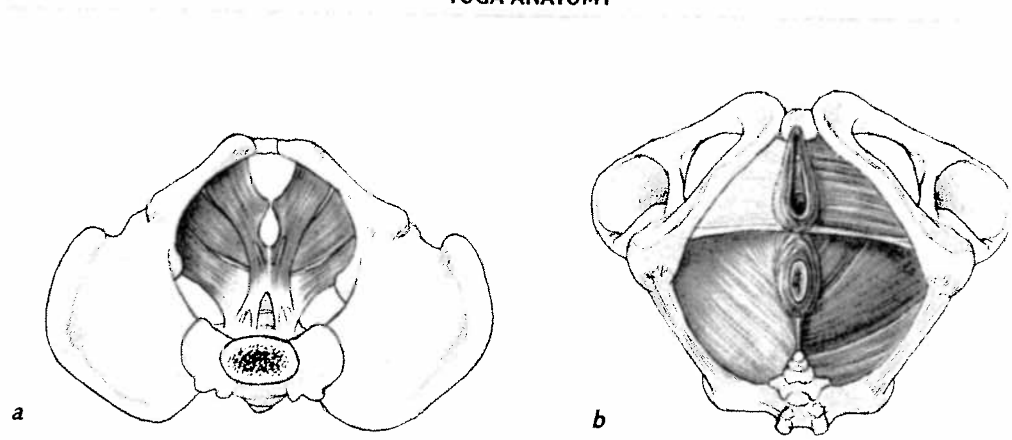

Figure 1.17 *(a)* The deepest muscles of the pelvic diaphragm, from above. *(b)* The pelvic floor from below, showing the orientation of superficial and deeper layers. The more superficial the lay the more it runs from side to side (ischia to ischia); the deeper the layer, the more it runs front to back (pubic joint to coccyx).

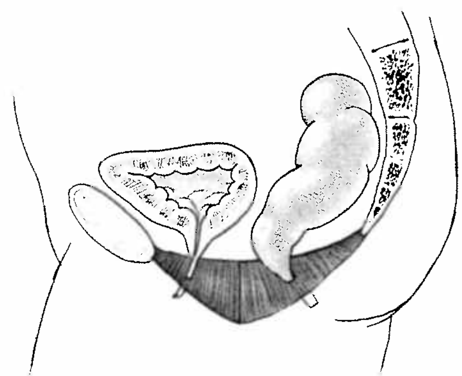

Figure 1.18 The action of the more superficial perineal fibers (figure 1.17*b*) are associated with the anal and urogenital sphincters and the downward movement of apana (i.e., the elimination of solid and liquid waste). The action of deeper fibers of the pelvic diaphragm (figure 1.17*a*) are associated with the upward movement of apana (i.e., the elimination of gaseous waste through exhalation).

Vocal Diaphragm

The gateway to the respiratory passages is the glottis, shown in figure 1.19, which is not structure but a space between the vocal folds (cords). Yoga practitioners are accustome to regulating this space in various ways, based on what they are doing with their breatł voice, and posture. When at rest, the muscles that control the vocal cords can be relaxe so that the glottis is being neither restricted nor enlarged (see figure 1.20*a*). This occurs i sleep and in the more restful, restorative practices in yoga.

When doing breathing exercises that involve deep, rapid movements of breath (such a kapalabhati or bhastrika), the muscles that pull the vocal folds apart contract to create larger passage for the air movements (see figure 1.20*b*). When the exercises call for long deep, slow breaths, the glottis can be partially closed, with only a small opening at the bacl of the cords (see figure 1.20*c*). This is the same action that creates whispered speech; i yoga it's known as *ujjayi*,[8] "the victorious breath."

[8] *U* denotes *udana*, which refers to the upward flowing prana in the throat region. *Jaya* means "victory."

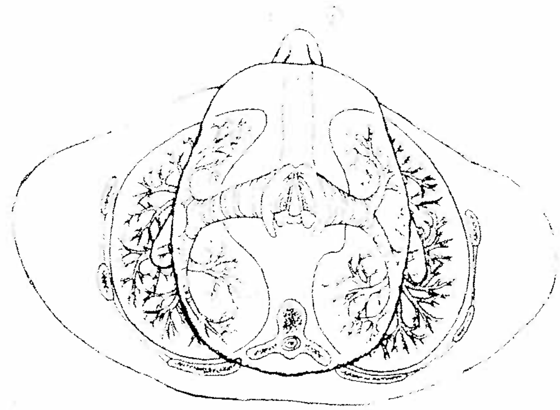

Figure 1.19 The pathway of air (in blue) into and out of the lungs.

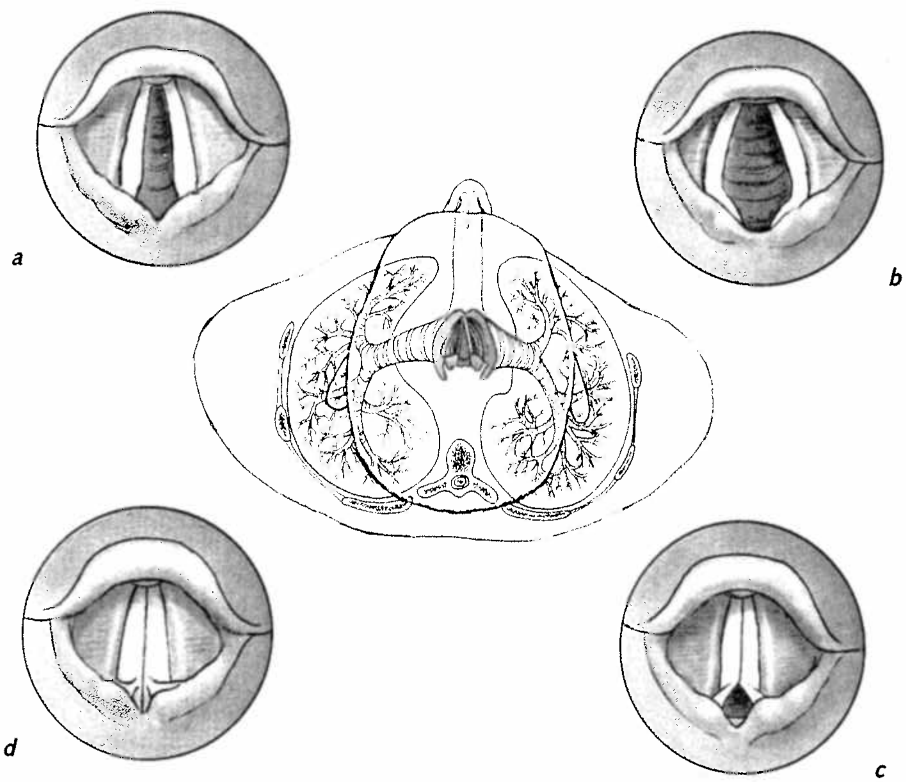

Figure 1.20 Position and location of vocal folds: *(a)* relaxed position, *(b)* maximal opening for forced respiration, *(c)* slightly opened for whispered speech (or *ujjayi*), *(d)* closed for speaking (phonation).

When making sound and during the chanting practices of yoga, the cords are pulled together into the phonation position (see figure 1.20*d*). The air pushing its way through them vibrates, creating sound. The pitch (and to some extent the length) of the sound is determined by how much tension is used to hold the cords together.

The Bandhas

All three diaphragms (pelvic, respiratory, and vocal) plus ujjayi come together in yoga mov ments that are coordinated with inhaling and exhaling. In addition to giving more length a texture to the breath, the "valve" of ujjayi creates a kind of back pressure throughout t abdominal and thoracic cavities that can protect the spine during the long, slow flexion a extension movements that occur in vinyasas such as the sun salutations. In yogic terms, the actions of the diaphragms (bandhas) create more sthira (stability) in the body, protecti it from injury by redistributing mechanical stress. An additional effect of moving the bo through this resistance is the creation of heat in the system, which can be used in ma beneficial ways. These practices are referred to as *brahmana*,[9] which implies heat, expa sion, and the development of power and strength as well as the ability to withstand stres Brahmana is also associated with inhaling, nourishment, prana, and the chest region.

When relaxing the body in the more supported, horizontal, restorative practices, rememb to release the bandhas and glottal constrictions that are associated with vertical postur support. This relaxing side of yoga embodies the qualities of *langhana*,[10] which is assoc ated with coolness, condensation, relaxation, and release as well as the development c sensitivity and inward focus. Langhana is also associated with exhaling, elimination, apan and the abdominal region.

Because the ultimate goal of yoga breath training is to free up the system from habitua dysfunctional restrictions, the first thing you need to do is free yourself from the idea tha there's a single right way to breathe. As useful as the bandhas are when supporting you center of gravity and moving the spine through space, you need to release the forces o sthira in the system when pursuing the relaxation and release of sukha.

If yoga practice leads you to more integrated, balanced breathing, it's because it train your body to freely respond to the demands that you place on it in the various position and activities that make up your daily life.

[9] The Sanskrit root *brh* can mean "to grow great or strong," "increase," "to make big or fat or strong," and "expand."

[10] *Langhana* is a term that originates in Ayurveda, the ancient Indian system of medicine, and it refers to practices such as fasting that reduce, or eliminate, elements from the system.