What Yoga Therapists Should Know About the Anatomy of Breathing

Introduction

There are staggeringly vast numbers of people in this country suffering from breathing related disorders; particularly when factoring in related maladies such as hypertension, back pain and depression.

Not surprisingly, similarly large numbers of people are seeking out alternative approaches to healing. A 2002 CDC study[1] on Complementary and Alternative therapies found that the most popular method of natural healing (other than prayer and nutritional supplements) is deep breathing exercises, with 12 percent of the population practicing. Another 8 percent of Americans say they practice meditation and 5 percent practice yoga for natural healing. We can only expect that these numbers have increased significantly in the past four years.

These trends indicate that for many millions of people, the way they breathe plays a significant factor in disorders that affect their health, as well as providing the means to restoring that health.

In terms of sheer numbers, no profession has a greater influence over the way people are trained to breathe than yoga teachers, and the demand for our services has increased exponentially over the past decade.

If yoga teachers have such an effect on how the public is trained to breathe, what factors influence the way yoga teachers are trained to teach breathing? The key factor, it seems, is tradition. Oft-repeated, outdated imagery along with inaccurate or unclear anatomical and physiological information have persisted in teacher training programs for half a century in spite of enormous advances in breath science.

Overview

In this article, I will summarize the four most common confusions about breathing that

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[1] U.S. Dept. of Health and Human Services: *Complementary and Alternative Medicine Use Among Adults: United States, 2002***.** Advance Data No. 343. 20 pp. (PHS) 2004-1250 http://www.cdc.gov/nchs/pressroom/04news/adultsmedicine.htm

have been compiled from a review of relevant literature.

The emerging field of Yoga Therapy offers its practitioners a singular opportunity to provide the public with accurate and useful information about breathing. In order to accomplish this, I will present basic definitions, anatomical information and analogies that can help to dispel each of the common confusions that have surrounded breathing methodology.

To conclude the article, I will summarize my anatomical information while highlighting correlated principles from the Yoga Therapy tradition of T.Krishnamacharya and T.K.V. Desikachar.

Four Common Confusions about Breathing

Last year, as part of my preparation for producing "The Future of Breathing" symposium at Kripalu Center for Yoga and Health, I wanted to review and evaluate traditional breathing information objectively. With the support of Kripalu, and the skilled research of Danna Faulds, we conducted a review of the breathing-related source material for the major Yoga teaching traditions. This survey revealed a number of flawed assumptions and outright errors related to breathing and breath anatomy that have remained both consistent and largely unchallenged through most of the history of Yoga teaching in America. Most of this confusion can be classified into the following four broad categories:

Confusion #1: Context dropping

This common error most often appears as either an explicit or implicit suggestion that there is a "right" or "proper" way to breathe without stating the context that gives rise to that breathing method. Context refers to the conditions unique to each individual's history, condition and goals. Context also refers to activity and body position – all of which significantly affect breathing patterns.

Since individual intentions, body type, shape and orientation all create different conditions for breathing, it's clear that no one pattern could suffice to deal with all of them. In other words, there is no one right way to breathe that will work under all conditions, and implying that there is only encourages people to create breathing habits

that make their systems less adaptable to change.

My simple, comprehensive definition of breathing as shape-change will help to dispel this confusion, and clarify the context in which breathing patterns arise.

Confusion #2: False dichotomy between diaphragmatic, non-diaphragmatic breathing

This error arises from the commonly stated bromide that "belly" breathing equals correct diaphragmatic breathing, and "chest" breathing equals incorrect non-diaphragmatic breathing. The idea that "correct" breathing involves the proper use of the diaphragm is true enough, but to equate diaphragmatic breathing exclusively with abdominal movement, and ribcage expansion with non-diaphragmatic (accessory) breathing is incorrect, because the diaphragm is capable of creating chest as well as belly movement.

This error arises from the lack of recognition that the diaphragm can mobilize the ribcage without the aid of the accessory muscles, and it leads to teachers making the seemingly helpful observation: "You're not using your diaphragm." Saying this to a non-paralyzed person is essentially the same as telling them they are dead – for it is the rhythmic contraction of the diaphragm that is the tangible manifestation of Prana expressing itself through a human form.

A corollary result of this confusion is that many students' breathing patterns are evaluated only by the location of shape change in the body, i.e.: belly breathing is good, chest breathing is bad. In reality, it is possible for breathing to manifest as tense, disordered belly movement, or relaxed, integrated chest movement. An excessive focus on the region of shape change as an indicator of "correct breathing" can blind us to many other, more relevant qualities of the breath.

My analysis of the 3-dimensional action of the diaphragm's muscle fibers, and my subsequent metaphor comparing the diaphragm to the engine of a car will help to clarify this confusion.

Confusion #3: Confusion between respiratory shape changes and regional ventilation

Here is a passage from a book on pranayama by one the world's most respected teachers, but it could have come from any yoga book:

> *Respiration may be classified into four types:*
> *High or clavicular breathing, where the relevant muscles in the neck mainly activate the top parts of the lungs.*
> *Intercostal or midbreathing, where only the central parts of the lungs are activated.*
> *Low or diaphragmatic breathing, where the lower portions of the lungs are activated chiefly, while the top and central portions remain less active.*
> *In total or pranayamic breathing, the entire lungs are used to their fullest capacity.*[2]

Here, the author speaks of "lung activation," which could be interpreted correctly (which is rare) or incorrectly (which is far more common).

The correct interpretation refers to the way lung tissue follows the ribcage and diaphragmatic breath movements (see "The Diaphragm's Relations: Organic Connections" later in this article).

The incorrect interpretation of "lung activation" is to equate it with local air movements in the upper, middle and lower portions of the lungs (regional ventilation). Simply stated, this error results from confusion between the concept of "breath" and the concept of "air."

Air moves into and out of the lungs via the pathway of the bronchial tree. This pathway is not affected by the sequence of shape change in the cavities of the chest and abdomen. These differing breathing patterns refer to some of the ways in which we manipulate the accessory breathing muscles in order to produce specific respiratory shape changes, but that is not the same thing as isolating the ventilation in the corresponding regions of the lungs.

In other words, contrary to what most teaching language implies, "belly breathing" does not fill the base of the lungs, "intercostal breathing" does not fill the middle of the lungs, and "clavicular breathing" does not fill the tops of the lungs.

Understanding that the accessory muscles "steer" the direction of the breath helps

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[2] *Light on Pranayama*, by B.K.S. Iyengar, (New York: Crossroad, 1981) p. 21

to clarify this confusion.

Confusion #4: Deep Breathing and More Oxygen is always a good thing

To read many yoga and breathing books, one could get the impression that deep breathing and oxygenation are the holy grails of health, well-being and enlightenment. The assumption is that the more carbon dioxide you get rid of and the deeper you breathe, the more oxygen you get in, and the healthier you'll be. The fact is, not enough carbon dioxide is dangerous, deep breathing is only occasionally appropriate, and too much oxygen is toxic.

Breathing patterns should always be linked to your body's metabolic needs.[3] If your level of activity requires a larger than usual supply of oxygen, deeper or more rapid breathing is perfectly appropriate. Those same patterns of breath, however, if applied to a resting state of metabolic activity would produce blood alkalosis (hyperventilation).

Your body has homeostatic mechanisms that prevent a toxic excess of oxygen from building up in the tissues.[4] The idea that one can improve health by increasing O2 concentrations in the blood is physiologically incorrect, and shouldn't be confused with the immense relief that accompanies a deep, freeing breath pattern. In fact, freeing the breath allows respiratory activity to more closely match body metabolism by releasing excessive, oxygen-hungry tension from the breathing musculature.

Your body is many times more sensitive to changes in blood levels of carbon dioxide than it is to oxygen. Carbon dioxide plays a critical role in helping hemoglobin transport oxygen from your blood to your body's tissues. If you don't have enough CO2 in your blood, the O2 gets held too tightly by the hemoglobin and not enough oxygen will be released into your tissues. The idea that one can improve health by ridding oneself of excess CO2 is physiologically incorrect, and shouldn't be confused with the simple act of exhaling more effectively (which is a prerequisite for a deep inhale).

Understanding that healthy breathing is linked to metabolic activity and normal CO2 levels will help to clarify some of these issues.

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[3] *The Psychology and Physiology of Breathing* by Robert Fried Ph.D. (New York: Plenum Press 1993) p. 34

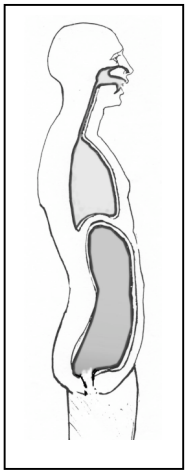
[4] *ibid*: Fried p. 29

Dispelling Confusion: Simple Definitions, Anatomy and Imagery

Breathing Definition

The Oxford American Dictionary defines breathing as: "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.

Movement in the two cavities



A simplified image of the human body divides the torso into two cavities, the thoracic and abdominal. These cavities share some properties, and have important distinctions as well. Both contain vital organs: the thoracic contains the heart and lungs; the abdominal contains the stomach, liver, gall bladder, spleen, pancreas, small and large intestines, kidneys, 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 - the roof of the abdominal cavity and the floor of the thoracic.

Another important shared property is that they are mobile – they change shape. It is this shape-changing ability that is most relevant to breathing, because without movement, the body cannot breathe at all.

Change in the Abdominal Cavity: Shape, *Not* Volume

Although both the abdominal and thoracic cavities change shape, there is an important structural difference in how they do so.

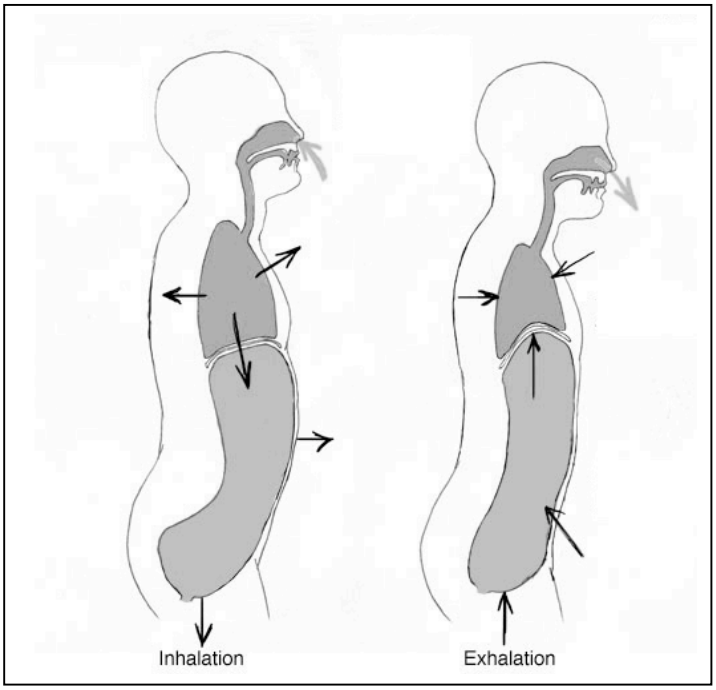
The abdominal cavity changes shape like a flexible fluid-filled structure such as a water balloon. Think of what it's like to hold a water balloon and imagine what happens when you squeeze one end of it - the other end bulges. This is because water is non-compressible. Your hand's action only moves the 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. This is because in the context of breathing, the abdominal cavity changes shape, but not volume.

In 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 due to expanded abdominal organs (stomach, intestines, bladder). It's useful to note that any increase of volume in the abdominal cavity will tend to produce a corresponding decrease in the volume of the thoracic cavity. This is why it's harder to breathe after a big meal, before a big bowel movement, or when pregnant.

Change in the Thoracic Cavity: Shape *And* Volume

In contrast to the abdominal cavity, the thoracic changes both shape and volume; it behaves like 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, and 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.



To sum up the distinction between the two cavities as regards breathing: the abdominal cavity changes shape but *not* volume, and the thoracic cavity changes shape *and* volume.

Volume and Pressure

As in the example of an accordion bellows, volume changes in the thoracic cavity result in movement of air. Volume and pressure are inversely related -- when volume increases, pressure decreases, and when volume decreases, pressure increases. Since air always flows towards areas of lower pressure, increasing the volume inside an accordion - or the thoracic cavity - will decrease pressure and cause air to flow into it. This is an inhale.

Pressure/Volume Shift and Shape Change

Let's now imagine the thoracic and abdominal cavities as an accordion stacked on top of a water balloon; movement in one will necessarily result in movement in the other. Recall that during an inhale, 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 exhale is a passive reversal of this process. The thoracic cavity and lung tissue - which have been stretched open during the inhale - spring back to their initial volume, pushing the air out and returning the abdominal cavity to its previous shape. This is referred to as a "passive recoil." It's important to note that any reduction in the elasticity of these tissues will result in a reduction of the body's ability to exhale passively –leading to an increase of muscular breath effort and a host of respiratory problems.

In breathing that involves active exhaling (such as blowing out candles, speaking, 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, or the thoracic is pushed downward into the abdominal, or any combination of the two.

An Expanded Definition of Breathing

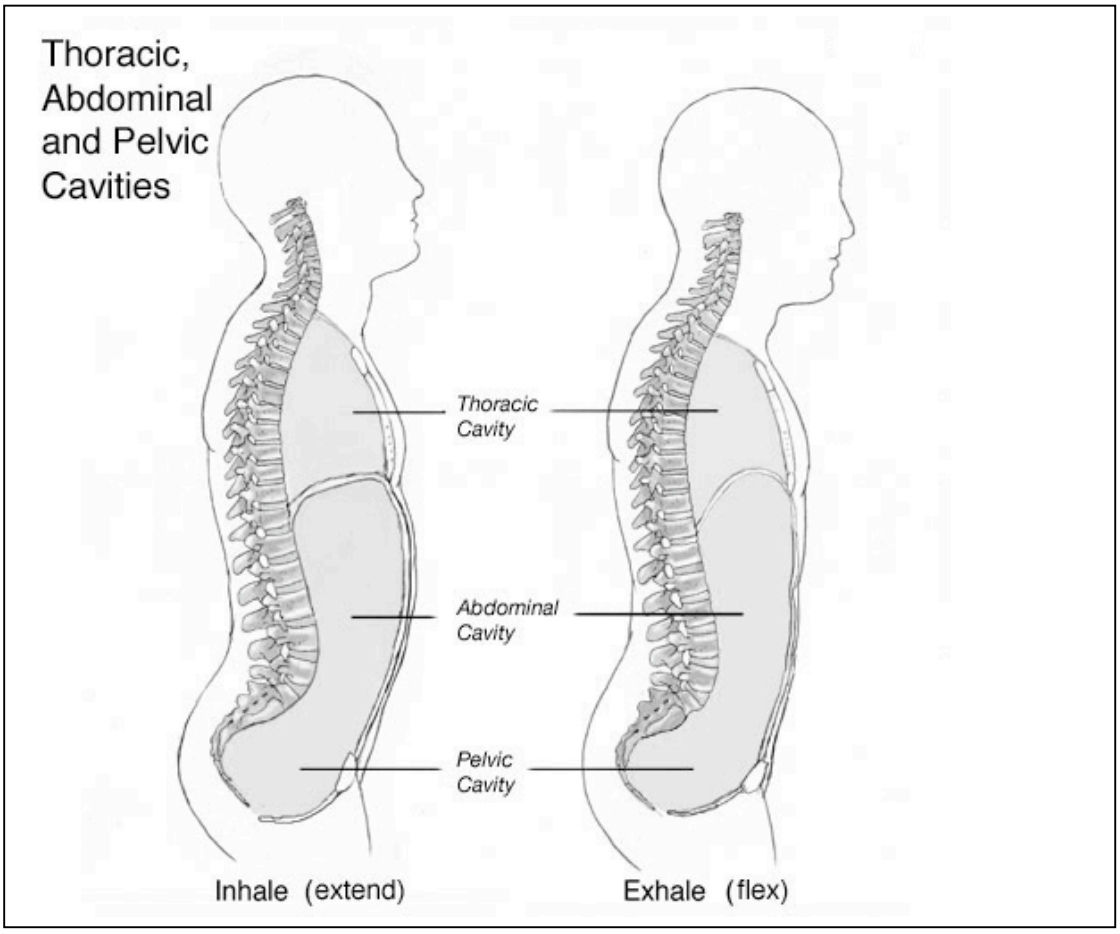
Here's our expanded definition of breathing:

"*Breathing is the intaking and expelling of air in the lungs, caused by changing the shape of the thoracic and abdominal cavities.*"

Defining breathing this way not only tells us what it is, but how we do it. This has profound implications for Yoga practice, as it can lead us to examine the supporting,

shape changing structure that occupies the back of the body's two primary cavities - *the spine*. This is why breathing and spinal movement are so intimately connected: flexion of the spine IS the shape change that reduces thoracic volume (exhale) and spinal extension IS the shape change that increases thoracic volume (inhale).

Additionally, as we shall soon see, the musculature of the breathing mechanism IS the musculature of postural support.



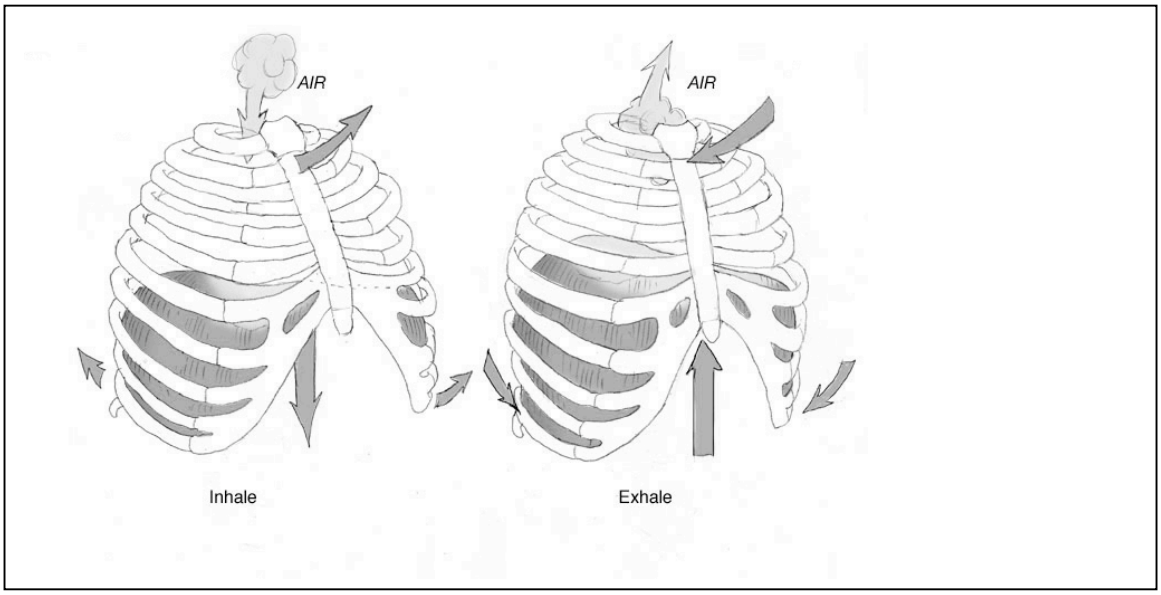
Answer to Confusion #1: Breathing Occurs in a Context

Gravity, posture, activity, habit, intention are just some of the factors that affect the shape-changing activities of the body cavities (breathing). To imply that there is one correct pattern of shape-changing (such as belly bulging) is to divorce breathing from the reality in which it occurs: individual human bodies engaging in an infinite number of activities on a planet with a gravitational field.

The goal of breath training is to free up the system from habitual, dysfunctional restrictions -- and the first thing we need to free the breath from is the idea that there's a single right way to do it. Integrated breathing means that the breathing mechanism is able to freely respond to the demands that we place on it in the wide variety of positions and activities that comprise our daily lives.

Breathing Shape Change is Three-Dimensional

The lungs occupy a 3-dimensional space in the thoracic cavity, and when this space changes shape to cause air movement, it changes shape 3-dimensionally. Specifically, an inhale involves the chest cavity increasing its volume from top-to-



bottom, from side-to-side and from front-to-back, and an exhale involves a reduction of volume in those same three dimensions.

Because thoracic shape change is inextricably linked to abdominal shape change, we can also say that the abdominal cavity 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. In a living, breathing body, there can be no thoracic shape change without abdominal shape change. This 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.

In order to understand how a single muscle – ***the diaphragm*** - is capable of producing all this movement (its actions), it is necessary to understand its definition, location, shape attachments and relations.

The Diaphragm – a definition

Just about every anatomy book describes the diaphragm as the principal muscle of breathing. Let's use our expanded definition of breathing, along with our "3-D" observation, to get a better understanding of this remarkable muscle:

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

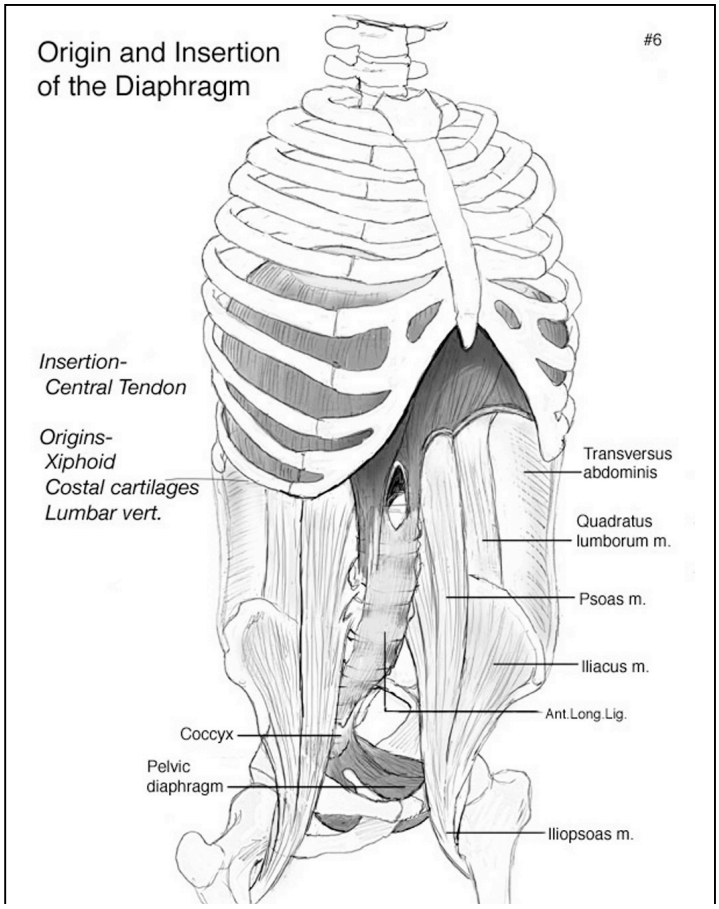
The Diaphragm – location

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 I describe it.

The Diaphragm – Shape

The deeply domed shape of the diaphragm has evoked many images: jellyfish, parachute, helmet or mushroom. 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-domed 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.

The Diaphragm's Attachments – Origin and Insertion

Origin: The lower edges of the diaphragm's circumference originate from three distinct regions: the bottom of the sternum, the base of the ribcage, and the front of the lower spine. These three regions form a continuous rim of attachment for the diaphragm, and 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%) originates on flexible tissue: the costal cartilage of ribs 6 thru 10 and the arcuate ligaments which bridge the span from the 10^{th} rib's cartilage to the floating 11^{th} and 12^{th} ribs, and from there to the spine.

Insertion: 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 onto itself – its own central tendon, which is fibrous non-contractile tissue.

The Diaphragm's Relations: Organic Connections

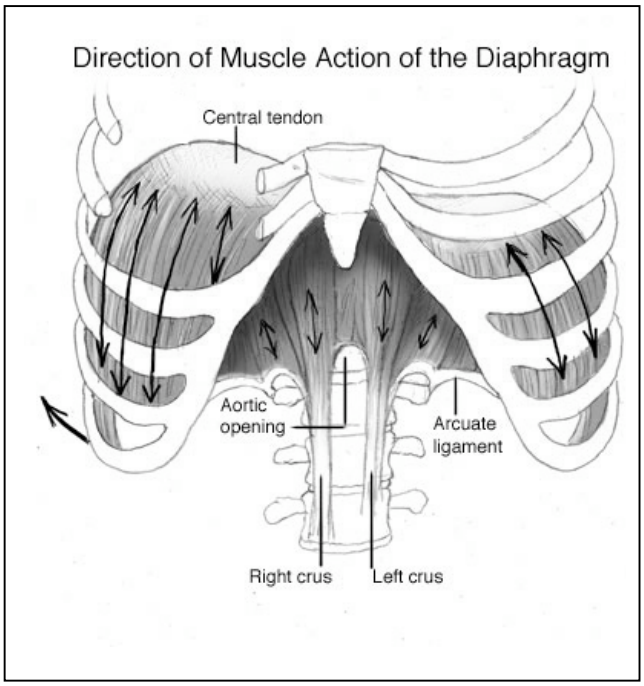
The central tendon of the diaphragm is a point of anchorage for the connective tissue that surrounds the thoracic and abdominal organs. The names of these important structures are easily remembered as the "Three P's."

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

Every organ has a membrane that tightly enwraps it, called the **visceral membrane**. Outside of the visceral is another layer that anchors the organ to the body. This outer membrane is the **parietal membrane**.

It is the parietal membranes that attach the organs to the diaphragm and the inner surfaces of the thoracic and abdominal cavities. 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 wellbeing of the organs is abundantly evident.



The Diaphragm's Action: Basics

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 its muscular action. Recall that the horizontal central tendon is non-contractile, and can move only in response to the contraction of the muscular fibers, which insert onto it.

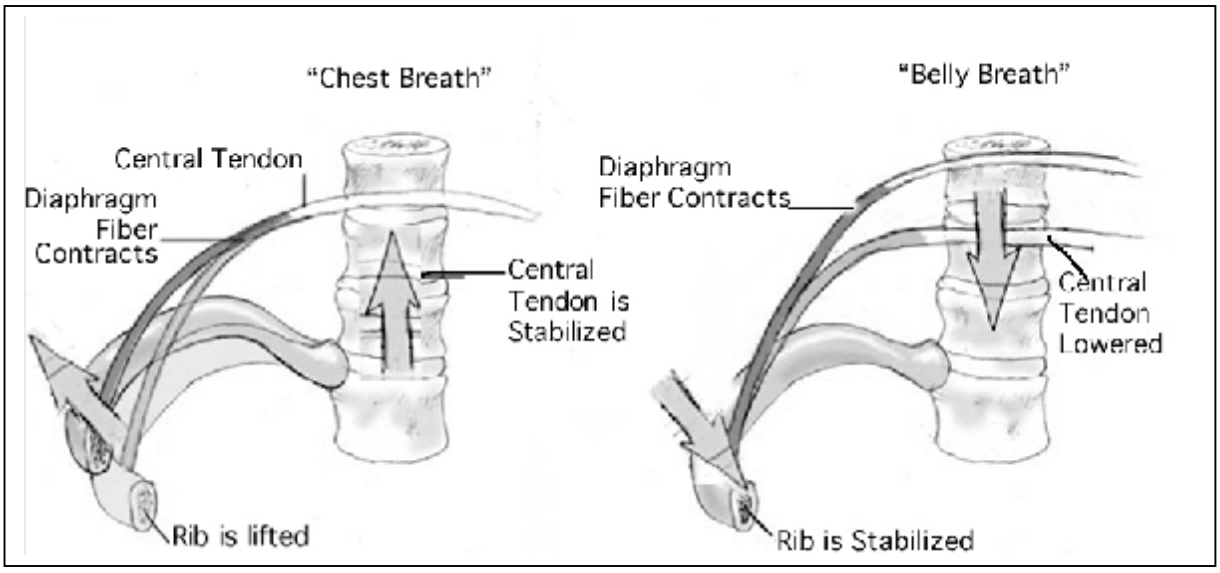
Like any other muscle, the contracting fibers of the diaphragm pull its insertion and origin (the central tendon and the base of the ribcage) towards each other. It is this action that is the fundamental cause of the three dimensional thoraco-abdominal shape changes of breathing.

As with any muscle contraction of the body, the movement it produces is a question of whether origin moves towards insertion, or insertion towards origin. Stated simply, this will depend upon which end of the muscle is stable, and which is mobile.

The Diaphragm's Action: Origin/Insertion - Stable/Mobile

The muscular action of the diaphragm is usually associated with a bulging[5] 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 ribcage) is stable, and its insertion (the central tendon) is mobile.

[5] 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 – for the same reason we would say a water balloon is bulging when we squeeze one end of it.



If the central tendon is stabilized, and the ribs are free to move, a diaphragmatic contraction will cause an expansion of the ribcage[6]. 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 "non-diaphragmatic 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 their 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 or not.

If it were possible to release all of the diaphragm's stabilizing muscles, and allow its origin and insertion to freely move towards each other, both the chest and abdomen would move simultaneously. This rarely occurs, as the need to stabilize the body's mass in gravity will cause many of the respiratory stabilizing muscles (which are also postural muscles) to remain active through all phases of breathing.[7]

The recognition that the diaphragm can mobilize the ribcage without the aid of the accessory muscles is a key element to understanding the integrated nature of breathing practices in yoga – especially the bandhas. It is the singular action of the diaphragm that is the prime mover of the thoracic and abdominal cavities. The specific patterns that arise

[6] This is what happens during inhale while correctly applying Mula Bandha.
[7] This also explains why babies' breath goes everywhere: they aren't standing up yet!

in Yoga asana, bandha or breathing practices result from the action of muscles other than the diaphragm that can change the shape of the cavities: *the accessory muscles.* In order to better understand this principle, the analogy of a car and its engine is very useful.

Answer to Confusion #2: The Diaphragm is the "Engine" of 3-D Shape Change

The engine is the prime mover of the car. All the movements that contribute to a car's functioning are generated by the engine. In the same manner, the three dimensional, abdomino-thoracic shape change of breathing is primarily generated by the diaphragm.

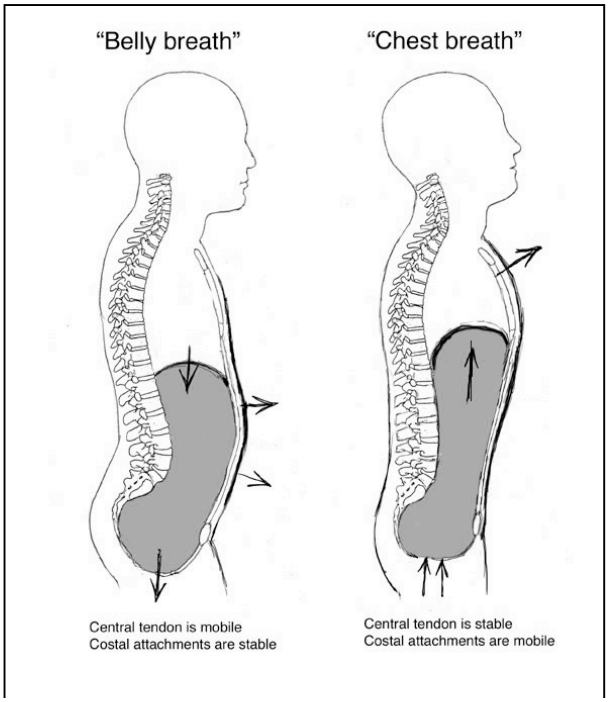
To say that diaphragmatic action is limited to the abdominal bulging commonly referred to as "belly breathing" is as inaccurate as asserting that a car's engine is only capable of making it go forward – and that there must be some other source of power that governs reverse movement. Just as this automotive error is linked to not understanding the relationship of the car's engine to its transmission, the breathing error is linked to not understanding the relationship of the diaphragm to the accessory muscles.

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

Answer to Confusion #3: The Accessory Muscles "Steer" the Breath – not the Air

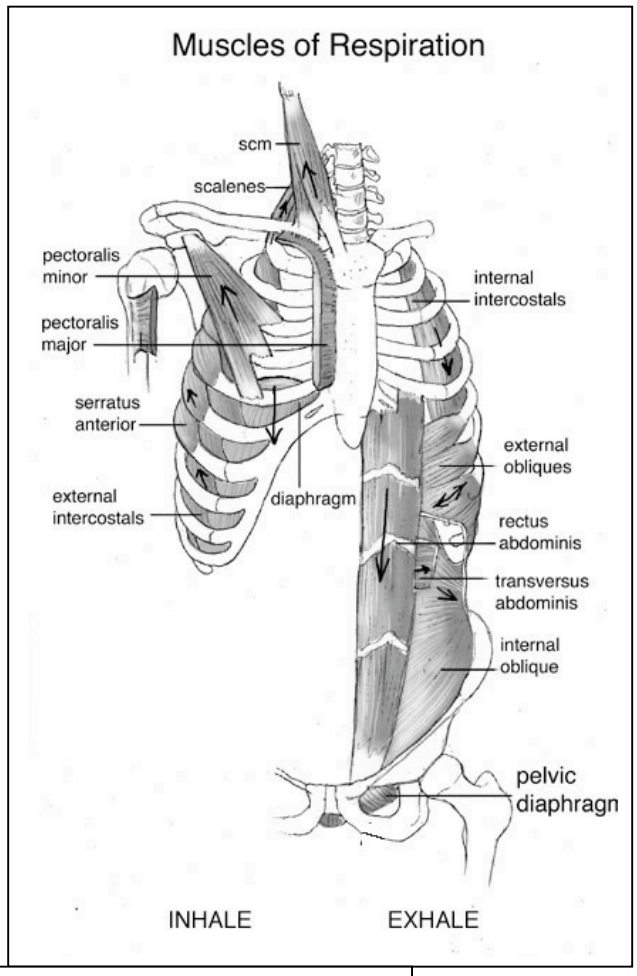
Since the diaphragm, in an unobstructed state, will create 3-D shape change in the thorax and abdomen, intentionally isolating the breath in one dimension requires us to block the other dimensions of movement. I like to refer to this as "steering" the breath.

We don't steer our car with its engine. In order to control the power of the engine, and guide it in a particular direction, we need the mechanisms of the



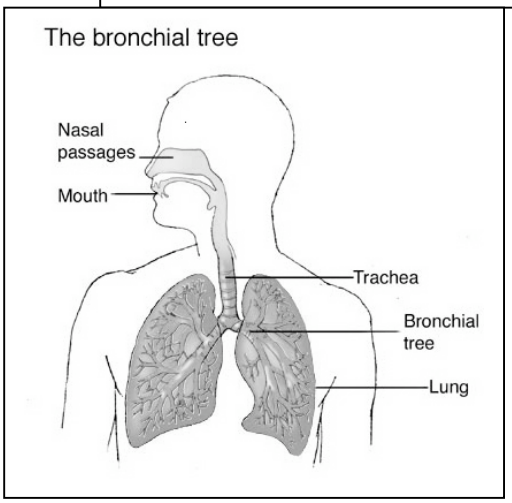
transmission, brakes, steering and suspension.

In the very same way, we don't "steer" our breathing with the diaphragm. As with a car's engine, all we directly control about the diaphragm is the speed/timing of its function. In order to control the power of the breath, and guide it into specific patterns, we need the assistance of the accessory muscles – the muscles other than the diaphragm that change the shape of our thoracic and abdominal cavities.



The accessory breathing muscles include the abdominal group, intercostal group, sternocleidomastoids, scalenes, pectoralis minor, serratus anterior, and a host of other muscles that stabilize them.

It is important to note that what we are "steering" with the accessory muscles is BREATH (shape-change), not AIR. Just because a particular region of the chest is moving more than another does not mean that there is more air going into the lung just beneath that movement. [8]. A look at the structure of the bronchial tree will reveal the pathway of lung tissue ventilation. This is not altered by the pattern of abdomino/thoracic shape-change.



It's understandable that we make this error, because we don't have direct sensory awareness of lung tissue, but do we have direct feedback from the breathing musculature – thus, it's easy to confuse one with the other.

[8] This is referring to what occurs in a single breath, which is a distinct issue from the chronic constrictions in lung tissue due to injury, disease, or habit – all of which can affect the elasticity of the lung, and thus its ability to expand fully.

Answer to Confusion #4: Healthy Breathing is Linked to Activity and CO2 Levels

The shape, depth, rhythm and volume of our breath is a reflection of our habits, training, intentions, body position and state of mind – to name just few of the myriad factors that influence our breathing.

Faulty concepts about the breath can also be a significant source of breathing difficulties, and I frequently encounter this in my Yoga Therapy practice. One of the most common patterns I observe is the trained yogi's tendency to do deep, slow Ujayyi breathing even when lying supine on a treatment table. Since this pattern is associated with vertical postural support, I usually ask why they are doing Ujayyi in a context where horizontal release is more appropriate. The usual reply that they dodn't even know they are doing it, and they find it difficult to release the pattern even after several attempts.

This pattern (among many others) is linked to a pervasive assumption in the Yoga world that breathing should ALWAYS be deep and full. This single absurdity is perhaps responsible for more dysfunction than any other I've encountered. As you read these words, quickly check your breathing. Is it deep or shallow? Unless you are reading this journal while taking a walk, or exercising on a treadmill, the answer should be quiet and relaxed[9]. This is because your body is at rest, and doesn't require a huge supply of oxygen to fuel the minimal metabolic activity of sitting and reading.

Yes, in Yoga we train ourselves to breathe deeply, and in a variety of unusual patterns, but this is only for the purpose of exploring the full potential of our breathing mechanisms in order to uncover and dismantle habitual patterns that obstruct normal function.

In other words, the end goal of practicing Pranayama (unusual breath patterns) is to achieve normal breathing (during those times when we're not doing specific, conscious breath exercises). Normal breathing, in the physiological sense, means that our everyday respiratory activity is consistent with our metabolic requirements. Since our metabolism changes with activity, so must our breathing patterns. Any inability of our breathing to accommodate changing conditions is, by definition, disordered breathing.

Breathing authority Dr. Robert Fried links the idea of normal breathing to tidal volume and breathing rate:

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[9] If , at rest, your breathing isn't quiet, it may indicate a state of anxiety, or a metabolic imbalance.

> *"The volume of air entering the lungs with each inspiration and expiration cycle is called tidal volume. The minute-ventilation of the lings is tidal volume per minute. Changes in minute-volume always reflect changes in metabolism in a healthy individual. High minute-volume reflects increased activity such as running, while low minute-volume reflects a low level of activity such as rest. In a healthy individual, breathing rate usually follows minute-volume. Rapid breathing accompanies a high minute-volume, while slower breathing goes with a lower minute-volume."*[10]

This relationship between the rate and volume of breathing is so tightly tied to metabolism that it is possible to predict the weight of a healthy individual at rest by measuring their minute-volume. After all, weight is an indicator of how many cells that person has to oxygenate on a moment-to-moment basis, and minute-volume is a measure of what the body is doing to provide that oxygen. Dr. Fried continues:

> *"That's why…inexplicably rapid or slow breathing, or high or low minute-volume, can indicate trouble and can also cause it…[it tells] us that the body is compensating for something unusual..."*[11]

From this perspective, the notion of taking deep, slow breaths at all times is revealed to be a recipe for metabolic mayhem. Similarly, the oft-repeated generalization that Yogic breathing is supposed to maximize oxygen intake and carbon dioxide elimination is just as flawed.

If we were truly able to accomplish this feat, then all Yogic breathing would, by definition, be hyperventilation – that is, the physiological state in which the blood contains too much oxygen and not enough carbon dioxide. This occurs when we "blow off" CO2 -- in other words, our breathing rate/volume is eliminating carbon dioxide from our system faster than it is being produced by our metabolism.

Why is this such a problem? After all, isn't CO2 a waste gas? If it's waste, shouldn't we get rid of as much of it as we can, so more of the fresh, healthy oxygen can come in and nourish our system?

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[10] *Breathe Well, Be Well* by Robert Fried, Ph.D: .John Wiley and Sons, 1999 p. 24
[11] *ibid.* p. 24

Well, it's not that simplistic. It turns out that oxygen, as important as it is, is toxic to the body in excess. It will literally burn (oxidize) tissue if not buffered by the body's protective mechanisms. And what of the "waste gas" carbon dioxide? It just so happens that the entire process of respiration is driven by CO2 – from the impulse that brings air into the body, to the chemical balancing act that delivers oxygen to our tissues, carbon dioxide is a critical player from beginning to end.

Take a relaxed breath…exhale comfortably…and wait.

Keep waiting…

What you are felling is a rise in blood CO2 that eventually signals your brain's respiratory center to send an electrical impulse through the phrenic nerve to contract your diaphragm. It is also the presence of CO2 in your blood that allows the hemoglobin to transport the oxygen from your blood into all your body's tissues.

When we've "blown off" too much CO2, our blood's acid-base balance is thrown into excessive alkalinity. When this happens, the hemoglobin holds too tightly onto the oxygen molecules, and doesn't release them into the body's tissues. So, even if we could maximize CO2 loss and O2 gain, this effect could only go as far as the bloodstream – where the oxygen will remain undelivered, bound to the hemoglobin. From this perspective, hyperventilation is a paradoxical state in which there's too much oxygen in the body's bloodstream, but not enough in its tissues.[12]

It's interesting to note that hyperventilation refers to the chemical condition of the blood, not to a particular pattern of rapid or shallow breathing. It is just as possible to hyperventilate while breathing slowly and deeply as it is while breathing rapidly and shallowly. The only requirement is that the minute-volume exceeds the body's ability to replace the CO2 that's being blown off.

In light of this anatomical reality, the seemingly innocent Yoga instruction to get rid of as much carbon dioxide as possible, so we can maximize oxygen intake doesn't seem so innocent. Better teaching language would refer to normalizing levels of O2 and CO2 in the body.

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[12] This is precisely why people who are having panic attacks are often advised to breathe into paper bags; the intention is to effect a sudden rise in blood CO2 which has been depleted through rapid breathing.

Summary and Perspective

Beyond uncovering the misconceptions that have seeped into our modern understanding of Yoga, a deeper look into the anatomy and physiology of breathing can also reveal the profound wisdom of our ancient tradition.

In the Yoga Therapy tradition of my teacher, T.K.V. Desikachar and his father T. Krishnamacharya, there are many hallmarks of a deep understanding of the anatomical principles under discussion here.

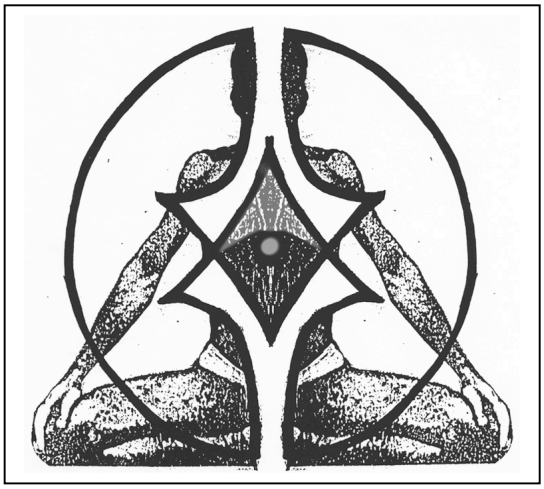
Krishnamacharya's dictum to always adapt the practice to the individual is a clear reference to the principle that Yoga techniques of breath and posture always occur in a context. To drop this context (confusion #1) is to run the risk of doing more harm than good by the misapplication of the powerful tools of Yoga Therapy.

Krishnamacharya also insisted that there is only one animating principle in the human system; the life-energy that manifests as our breath -- Prana. He asserted that Kundalini, rather than being a positive force, is an obstruction to Prana. This stands in distinction to other schools, in which Kundalini is viewed as a separate form of dormant spiritual energy, which creates a dichotomy between the "earthly" pranas that animate our physical bodies and the "spiritual" Kundalini that liberates our spirit.

This is reminiscent of the observation that the movement of the diaphragm is the physical manifestation of Prana in the body, and that there is only one form of breathing – diaphragmatic; not the correct/incorrect, belly/chest, diaphragmatic/non-diaphragmatic dichotomies perpetuated by most other approaches to breathing (confusion #2).

One of the most distinctive features of the Desikachar/Krishnamacharya lineage is the "top-to-bottom" breath that encourages the expanding inhale to proceed from the upper reaches of the thorax in a downward direction towards the abdomen. In the past, this used to be referred to as "upside-down" breathing by other traditions that taught their students to fill the lungs "from the bottom to the top."

Once the anatomy of the bronchial tree is clearly grasped, it becomes clear that it is impossible to fill the lungs from the bottom to the top (confusion #3), and that the "top-



to-bottom" method is simply linking the shape-change of breathing to the direction of airflow into the body. This orientation to the breath also links the flow of repiratory movements and spinal support with the deeper concepts of prana and apana.

Finally, by placing the breath at the core of asana, pranayama and meditation practice, the Krishnamacharya/Desikachar lineage hands us the ultimate tool for both effecting change and gathering feedback about the deepest levels of our system's function. By honoring the breath as our ultimate teacher and guide, we will be able to balance our physiology with our Yoga practice. The focus on the breath enables us to detect subtle changes and make minute adjustments that may be missed if we don't keep our breathing patterns integrated with our activities. (confusion #4).

It is my hope that this brief excursion into anatomical issues related to breathing will stimulate an ongoing dialogue – which in turn can lead to improved methods of education in Yoga Therapy training programs.

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This article contains material that is more fully explored in Leslie Kaminoff's book "Yoga Anatomy" published by Human Kinetics in November of 2006. The title of this piece is taken from a presentation that the author is scheduled to deliver at IAYT's SYTAR