Chapter 7
Breathing

Breathing - It seems easy enough to do, but every time I turn around I'm being reminded how to do it. Returning from a recent complementary and alternative medicine conference I reflect on how three different speakers gave instructions on how to breath. Two claimed that by expanding my belly when I inhaled, I would pull air deep into the base of my lungs where gas exchange occurs. Really? Is this true? As a physiologist I am always intrigued by the claims people make. I didn't spend much time puzzling the accuracy of this claim or the relevance, until my experience during the Sunday morning Chi Gung session.

I've never found standing in static poses especially enjoyable. My body dislikes the extra exertion it takes just to stand still. This day was no different. Not having practiced Chi Gung in over a year, it was a push for me to do many of the exercises. In addition, having a tendency to overachieve I was confused by the instructions. "Go only as far as comfortable." Followed by, "Okay, now stretch a little further."

There I was standing with my feet a little further than shoulder width apart and pointed inward 20 degrees. (Or was that 30 degrees. I couldn't really tell and for a moment I regretted not having a compass or protractor with me.) My arms were parallel to the ground stretched out at my sides and I was dutifully twisting at the waist. I had to keep returning my head back to center as my natural inclination was to twist my neck as well. Oh, and of course, I was supposed to breath through all this. The instructor was calling out "twist some more, hold, twist some more". Finally we were allowed to relax back to center. I then remembered I forgotten to breath. Well, not exactly. I certainly was still breathing, but I wasn't breathing in the way the instructor had just taught us.

The breathing instructions were to push out our stomach during the

inhale and on the exhale pull our stomachs in, forcing the air out of our mouths. This seemed easy enough. Over 20 years ago I'd learned about the common tendency of humans to tense abdominal muscles (keep the gut "sucked" in) and not allow free movement of the diaphragm during breathing. I was familiar with belly breathing as simply allowing the diaphragm to move freely. But this morning I was beginning to think, that perhaps I'd been doing it wrong all these years. Had I forgotten how to breath? Or perhaps I never knew how. As I was focused on following all the movement instructions these concerns and thoughts were just shadows at the periphery of my mind.

In any case, I took advantage of a brief pause in instructions to remove my sweater. All the exertion of the poses had left me feeling quite warm. Almost immediately after dropping my sweater to the floor, I began to feel light headed. Having fainted a few times in my youth and less frequently as an adult (since by then I learned to avoid standing stationary for long periods of time) I knew I was getting close to passing out. I collected up my sweater and walked to an out of the way place and lay down. Darn! I was looking forward to participating in this class since I'd seen the instructor perform some powerful displays of energy use at a conference some years earlier. I had hoped to learn her secrets.

Instead, lying there on the ground, I turned my attention to my body and wondered why I almost fainted.

I know I had fatigued my muscles. Both my arms and legs had been shaking during the standing postures. I speculated that the temperature drop when I removed my sweater may have resulted in systemic vasoconstriction. With the sweater on, my peripheral vessels had been dilated to allow for body cooling. It was plausible they constricted in response to the removal of my sweater. If the response was systemic then the blood vessels supplying my brain would also vasoconstrict. This would result in reduced blood flow to the brain and a concurrent

reduction in oxygen delivery, which could have led to my lightheadedness.

I continued to think...

I seem to always get light-headed when I breath through my mouth. Maybe exhaling through my mouth contributed to my current condition. But why would mouth breathing make a difference? Now there's a good question. Nose. Mouth. Shouldn't make much of a difference. Perhaps I breath more rapidly when I do mouth breathing? Hyperventilation results in excess removal of CO_2 from the body. The drop in CO_2 results in a pH increase and lightheadedness.

I first discovered the effects of hyperventilation in third grade. I remember coming in from recess and breathing quite heavily. We were instructed to put our heads down on our desks and rest for a little while. Next thing I remember was “waking up”. I was not tired, so I knew I hadn't fallen asleep. Yet, I also knew that I had lost consciousness. In the process of trying to figure out what happened, I learned that I could “pass out” by forcefully breathing. Interesting game at the time.

Although it is possible that mouth breathing causes hyperventilation in my case, I did not really believe that was what was going on. Wouldn't the teacher know to warn against this? In addition, other meditative practices and breathwork systems use this method of breathing. Maybe this method of breathing results in enhanced movement of Chi through the body. Perhaps I am not lightheaded due to pH changes, but due to the change in energy flow through my body. Now there is an idea.

As I lie there I note pressure proximal to my sternum and consider that I need to visit my primary health care provider (a medical intuitive/energy healer) to see if this represents a blockage. If Chi were moving more vigorously through my body and I had a blockage I would indeed feel uncomfortable. In fact, I remember when I first started to

do Chi Gung ten years prior. I had a hard time with a practice called dissolving due to a energy blockage in just that same spot.

“I have a tendency to third chakra blockages,” I think with a smile.

Round about this time the teacher's assistant walks up to check on me. Upon hearing I'd gotten dizzy she bends down to repeat the instructions on breathing. She claims that if I breath the way instructed, I would experience benefit. Apparently she had problems with lightheadedness when she first started this practice and found that focus on the deep belly breathing improved things. Although I believe she stopped because she cared about my state and wanted to help me, I found that she wasn't able to listen to where I was and meet me there. When I told her the forced breathing was uncomfortable, she told me that was simply because I wasn't used to it. She reminded me that belly breathing is the natural way since all babies breath that way. I couldn't figure out how to connect to what she was telling me. It was as if the possibility that I learned “belly breathing” 20 years ago never entered her mind.

With her hand on my belly (Did she ask permission to touch me?) she pushed on my belly to show me how I could contract even more after my exhale. Trying once again to connect with her, I commented that it didn't make sense to me to contract more when there was no more air coming out of my mouth. She assured me that with continued practice I would improve my inhale so that there would be more air to exhale. It crossed my mind to question why this was desirable, but I kept quiet instead.

Both the teacher and assistant thought that a perfect inhale was accompanied by a belly that sticks out and feels hard to the touch. I began to wonder about that. My personal experience suggests that tightening the abdominal muscles so that they feel hard always leads to an increase in lung pressure accompanied by a decrease in lung volume.

This would cause expiration not inspiration. Tight abdominal muscles certainly didn't seem like the best way to optimize the inhale capacity.

Despite a fairly negative experience at that Chi Gung session I returned home intrigued by the whole breathing thing. I experimented with slow breaths (2 per minute) and mouth breathing. I recruited my abdominal muscles and other muscles. I started to dredge my memory for lung physiology.

As far as we know, breathing is controlled by the respiratory centers in the brain stem. Its interesting that although we equate breathing with supplying the body with oxygen, changing oxygen levels do not result in changes in breathing unless oxygen levels drop dramatically. In normal situations the blood leaving the lungs is close to saturated with oxygen. Breathing faster or harder doesn't change this fact.

What the body really responds to is carbon dioxide levels. You see, CO_2 interacts with water to form carbonic acid. If CO_2 is high in the blood than carbonic acid levels increase and the pH goes down. The chemical reaction can be described by this equation:

$$CO_2 + H_2O \rightleftharpoons \underset{\text{carbonic acid}}{H_2CO_3} \rightleftharpoons H^+ + \underset{\text{bicarbonate}}{HCO_3^-}$$

Plasma pH is tightly controlled. Small changes in pH result in changes in protein structure that impair their function. Proteins are critical for all enzymatic activity, DNA activation, most transport into and out of cells and a variety of other things. While O_2 can fluctuate from 50 to 100 mmHg, a shift in pH from the norm of 7.5 to 7.4 will result in an immediate change in respiratory rate.

The literature describes two areas where CO_2 and/or pH are monitored by the body. One area is the peripheral chemoreceptors. These are chemoreceptors in the aortic and carotid bodies, areas rich in sensory

neurons that are found in the walls of both the aorta near the heart and the carotid artery in the neck. The other area is central chemoreceptors located in the medulla oblongata of the brain stem. Both areas sense changes in CO_2 as measured by pH changes and relay this information to the respiratory control center in the medulla oblongata.

The respiratory control center of the medulla oblongata is comprised of pacemaker neurons. Yes, that's pacemaker neurons. Just as the heart continues to beat automatically when removed from the body due to the presence of natural pacemaker cells, these neurons fire spontaneously to sustain rhythmic breathing. Inhalation occurs when theses neurons stimulate the contraction of the diaphragm and intercostal muscles and exhalation occurs when the excitatory message is inhibited. Inhalation is the active process. Exhalation occurs during relaxation.

The diaphragm is attached to the edges of the rib cage. When relaxed it moves upward in a shape that can be envisioned as an inverted bowl. When the diaphragm contracts, its bowl like shape flattens out like a tight drum, pushing the contents of the belly down. The external intercostal muscles are situated on the rib cage such that when they contract they lift the ribs out slightly thereby increasing the volume within the rib cage and correspondingly the lungs.

The mechanics of breathing are fascinating. Contraction of the diaphragm and intercostal muscles followed by relaxation. Over and over and over again. Human beings can be observed “breathing” as early as 10 weeks gestation. While newborns may lack the rhythmic pattern of older humans, they still breath by action of the diaphragm and intercostal muscles. This is the belly breathing I learned, the relaxation of the abdominal wall so that when the diaphragm contracts down the organs below it have room to move out of the way. This allows for enhanced lung filling.

The process described by the Chi Gung instructor involved recruitment

of additional muscles to force air in or out of the lungs. For this reason it can be referred to as forced breathing. When one starts to breath in, the diaphragm contracts down pushing the belly out and the parasternal and external intercostal muscles contract and lift and expand the rib cage. As one breathes even deeper the muscles of the neck, the sternocleidomastoid and scalenes, lift the collar bone and rib cage up further decreasing the pressure in the lungs and maximizing the inhaled lung volume.

During exhalation the diaphragm and parasternal and external intercostals are relaxed. To force out even more air, the internal intercostals and abdominal muscles (oblique, transversus, and rectus muscles), latissumus dorsi and quadratus lumborum are recruited. The abdominal muscles contract inward towards the spine. This reduces the space for the guts and they are pushed up into the relaxed diaphragm increasing the pressure in the chest cavity. The increase in pressure forces air out of the lungs. The latissimus dorsi wraps around the side of the body and is attached at the pelvis, sacrum, spine, lower ribs and upper arm. When contracted it will also act to depress the rib cage down and force out additional air. The quadratus lumborum (attached to the pelvis, lumbar spine and last rib) contract and pulls the rib cage down, further increasing the pressure inside the lungs.

As with any physical practice the more you practice forced air breathing the greater your capacity to do it. There is evidence that breathing parameters such as speed to empty lungs and breath holding time will increase. However, the adoption of forced breathing techniques by numerous spiritual practices suggests that their may be other, harder to measure, effects.

Now back to my original question. Does forced air breathing or even simple relaxed belly breathing allow air “deeper” into the lungs?

Keeping the abdominals contracted during inhalation prevents the

diaphragm from moving down fully when contracted. Breathing when the diaphragm is held up is characterized by very little belly movement while the chest continues to rise and fall. Since most of the action is in the upper part of the body this is sometimes called “shallow” breathing. Since the abdominal muscles are pushing back on the diaphragm the pressure within the chest remains relatively high and less air moves into the lungs. Since the body requires delivery of a regular amount of air, the shallow breather compensates by having a faster ventilation rate. Perhaps for every breath the deep breather takes the shallow breather will need two or three.

The term shallow suggests that the air is staying at the top of the lungs and not moving deep into the lungs. Is this really the case?

Lets consider lung anatomy. The lungs aren't just empty sacks like balloons. They are like a spongy tissue. Air moves into the body via a large open tube, but the airways of the lungs are finely branched networks of smaller tubes. The smallest airways are only one cell thick and end in clusters of little gas exchange rooms called alveoli. The alveoli are the “deepest” part of the lungs and they aren't concentrated at the top or bottom of the lungs. They are evenly distributed throughout the lungs. Gas exchange only occurs in the alveoli and the small airways that lead to the alveoli (respiratory bronchioles). The other airways in the lungs, such as bronchi and larger bronchioles, are responsible for conducting air into this respiratory zone. Since these passageways are not participating in gas exchange they are sometimes referred to as dead space.

If air doesn't get to the respiratory zone no gas exchange occurs and we die. So even a “shallow breather” is getting air “deep” into the lungs, otherwise they'd be dead. However, it is true that when someone breaths shallower the volume of their breath is smaller. Does this mean that they are getting less air into the respiratory zone? Yes and no. A typical relaxed breath brings in 500ml of air. (The volume of air that

moves in and out of the lungs during relaxed breathing is called the tidal volume.) The dead space of the conducting zone is a fixed volume of about 150ml. That means with each breath delivers about 350ml of fresh air to the respiratory zone. Any increase in the tidal volume, will increase the fresh air delivery, since the dead space is a fixed volume. So taking a slightly deeper breath and bring in an additional 100ml air (600ml total) will increase the fresh air by the full amount (100ml). It would appear that deep breathing would indeed bring more air deeper into the lungs. *At least on a breath to breath basis.*

However, shallow breathers tend to ventilate more rapidly. If our regular breather takes twelve 500mL breaths a minute they have a minute volume of 6 liters. The fresh air delivered would be 350 times 12 = 4.2 liters. Our shallow breather taking breaths of 400mL might take 20 breaths a minute. This gives them a minute volume of 8 liters. The fresh air would be less per breath (250mL) but this times 20 breaths per minute suggests that they would have 5 liters of fresh air delivered. So on an average the shallow breather and the deep breather are going to have the same amount of fresh air delivered to the gas exchange area.

In fact, this is how it has to be.

As mentioned previously, the body controls the rate of ventilation based on the levels of CO_2 in the blood. One can override these signals by voluntarily holding the breath, but this is generally uncomfortable. So if the breath is deep, one is comfortable taking breaths less frequently. If the breath is shallow, the body demands more frequent ventilation. On the surface it seems that there really is no advantage of deeper breathing in terms of gas exchange. Still, deeper breathing is more efficient. If a normal breather at 500ml tidal volume doubles the volume of their breaths to 1000 ml and reduces the frequency of ventilation by half (from 20 to 10) they would still have the same minute volume, but they would increase the fresh air delivery by 20%.

Normal relaxed breathing appears to provide the body with adequate gas exchange. Forced breathing will deliver more fresh air to gas exchange tissues leading to a slower ventilation rate. On average, all rates and depths of breathing will self regulate so that CO_2 levels in the plasma are held constant. While relaxed breathing is more comfortable to me, specific forms of forced or regulated breathing are chosen by people to enhance health and as part of spiritual practices. Many teachers present these breathing methods as beneficial. While claims that deep breathing supplies more oxygen don't make sense to me, deep breathing does activate the parasympathetic nervous system leading to reduction in stress response. Now there is something most of us can appreciate.