MODULE 4: THE SCIENCE OF BREATHING

LESSON 4: RESPIRATORY PHYSIOLOGY AND CHEMISTRY

A person can live for weeks without food and a few days without water, but only a few minutes without oxygen. Every cell in the body needs a constant supply of oxygen to produce energy, repair or replace itself, and maintain vital functions. The oxygen must be provided to the cells in a way that they can use. It must be brought into the body as air that is cleaned, cooled or heated, humidified and delivered in the right amounts.

In the previous lessons, we saw how the respiratory system is structured for this to happen. Now, we will look more closely at the physiology or functions of respiration as well as the mechanics and chemistry involved in breathing.

So far, we have learned about the conducting zone:

1. Air containing oxygen enters the body through the nose and the mouth; from there it passes through the pharynx or throat on its way to the trachea.
2. The trachea divides into 2 main airways called bronchi upon entering the lungs
3. The bronchi subdivide into smaller and smaller branches called bronchioles
4. After about 23 divisions, the bronchioles end at the alveolar ducts (air sacs)
5. The oxygen system is finally transferred into the blood stream at the alveoli

Now we learn about the respiratory zone where the process of ventilation, gaseous exchange takes place, and the role of the circulatory and nervous system.

Each alveolar sac is surrounded by capillaries having direct contact with each other. Gas exchange occurs through this alveolar-capillary membrane as oxygen moves into and carbon dioxide moves out of the bloodstream.

Although the 300 million alveoli in the lungs are microscopic, they have a total surface area equivalent to the size of a tennis court!

As we can see, the circulatory system is part of the system that is involved in transporting the oxygenated blood to the body's tissues and the de-oxygenated blood from the tissues back to the heart. Let's follow this process which happens in 4 stages:

1. Ventilation: Air travels through the conducting zone to the alveoli.
2. Pulmonary Gas exchange: Oxygenated blood gets diffused from the alveoli into the capillaries that surround them.
3. Gas transport: The alveolar capillaries link up to form larger vessels which carry the oxygenated blood to the left side of the heart. The heart then pumps this blood through the main artery, the aorta, which branches out into arteries, and further into tissue capillaries.
4. Peripheral Gas exchange: Oxygen then gets absorbed from the tissue capillaries to all the cells and mitochondria within them.

The carbon dioxide produced by the cells gets absorbed by the capillaries and this gets carried in the veins. These micro vessels then gather up to form tiny veins, then larger ones to link up to form the pulmonary circulation and transports this de-oxygenated blood to the right side (atrium) of the heart via the inferior and superior vena cava.

The heart then sends this blood to the lungs via the pulmonary veins to be oxygenated again through the alveolar-capillary membrane, and the cycle begins again.

The pulmonary veins transport this oxygenated blood to the left side (atrium) of the heart. The aorta is the main big artery that emerges from the left ventricle of the heart, branches out into smaller arteries and eventually into tiny tissue capillaries.

But what drives breathing?

Breathing in humans is both involuntary and voluntary.

Involuntary breathing

Involuntary breathing is regulated by the autonomic nervous system (ANS) which means that the breathing happens automatically without you having to think about it. There are various receptors in the body that send signals to the respiratory centre in the midbrain (medulla and pons)

- Chemo receptors in certain arteries pick up changes in oxygen, carbon dioxide and hydrogen levels
- Receptors in muscles and joints
- Pain receptors and emotional stimuli which act through the hypothalamus in the brain
- Stretch receptors in the lung
- Irritant receptors in the lung

The respiratory centre in the midbrain then sends the signals via nerves to the lungs and muscles of respiration.

Voluntary breathing

Breathing is the only autonomic process in the body that we can override consciously – the processing for this kind of breathing occurs in the higher centres of the brain - in the cortex.

Breathing mechanics

Inspiration:

- The contraction of the inspiratory muscles (principal inspiratory muscle is the diaphragm) causes the chest cavity to expand, creating a negative pressure.
- The resulting flow of air into the lungs is called inspiration.
- During a maximal inspiration, the diaphragm contracts forcing the abdominal contents downwards and outwards.

The external intercostal muscles, found between the ribs, are also involved. These muscles contract and raise the ribs during inspiration, thus increasing the diameter of the chest cavity. In addition to these muscles, the scalene muscle and the sternomastoid (accessory muscles) in the neck may be employed during extreme ventilation or in conditions of respiratory distress.

Expiration:

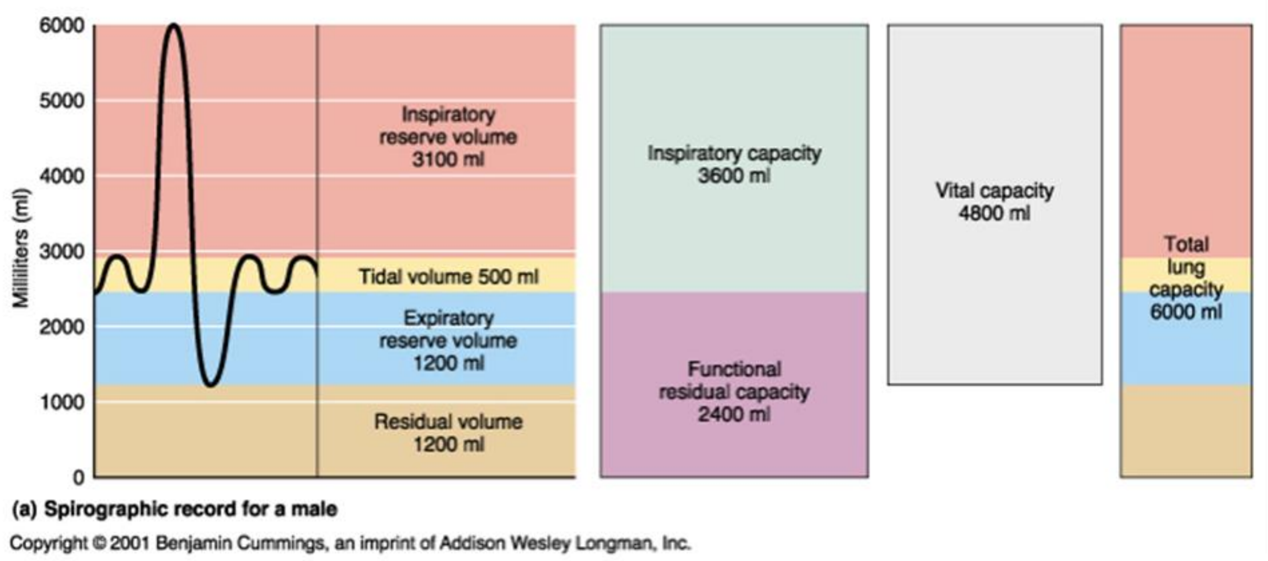
- Normal expiration is a passive process resulting from the natural recoil or elasticity of the expanded lung and chest wall. (However, when breathing is rapid, the internal intercostal muscles and the abdominal muscles contract to help force air out of the lungs more fully and quickly). A lung can be viewed as the opposite of a sponge. When a sponge is squeezed and released, its elasticity causes it to rebound to its larger initial size. At the end of an inspiration, the elasticity of the lung causes it to return to its smaller inter-breath size. The ability of the lung to do this is called elastic recoil.

The degree of stiffness or compliance of the lung tissue affects the amount of pressure needed to increase or decrease the volume of the lung. Lung compliance can affect elastic recoil. With increasing stiffness, the lung becomes less able to return to its normal size during expiration. This happens in conditions like emphysema.

The amount of airflow resistance can also affect lung volumes. Resistance is the degree of ease in which air can pass through the airways. It is determined by the number, length, and diameter of the airways. An individual with a high degree of resistance may not be able to exhale fully, thus some air becomes trapped in the lungs. This happens with asthma.

Lung volumes

As a breathworker, it is helpful to understand lung volumes and lung capacity.



Dead space

In respiratory physiology, dead space is the air that is inhaled by the body in breathing, but does not take part in gaseous exchange. Not all the air in each breath is able to be used for the exchange of oxygen and C02. About a third of every resting breath has no change in O^2 and CO^2 levels. In adults it is usually about 150ml.

The average resting respiratory rate is 12-16 breaths/minute, but because of dead space, taking deep breaths more slowly e.g. 10 breaths/minute is more effective than taking shallow breaths more quickly e.g. 20 breaths/minute. A large proportion of the shallow breaths is dead space and does not allow oxygen to get into the blood.

Total dead space can be divided into anatomical and alveolar dead space

Anatomical dead space: This is the gas that is found in the conducting system of the respiratory tract - such as the mouth and trachea where the air does not come into contact with the alveoli where gaseous exchange occurs.
The alveolar dead space: This is caused by air contacting alveoli without blood flow in their adjacent capillaries (i.e. ventilation without perfusion). As a result, no gaseous exchange can occur. Alveolar dead space is negligible in healthy individuals, but can increase dramatically in some lung diseases.

CO^2: It's good For You and Tasty Too!
Over 70% of the population tested to date shows a deficiency of carbon dioxide in their system: a condition known as chronic hypocapnia. In other words, if you are like most people, you are probably "blowing off" too much CO^2 when you breathe: a condition known as chronic hyper-ventilation. Over breathing means that the rate of ventilation is more than what is required by the rate of production of CO^2 by the tissues. This CO^2 deficit causes the micro vessels to constrict, so that even though one is huffing and puffing, the vital supply of oxygen to your cells and tissues is reduced - a condition known as chronic hypoxia. We need a certain level of carbon dioxide in the system in order stimulate the transfer of oxygen from the blood to the cells and tissues that need it. CO^2 is responsible for the dilation and the constriction of blood vessels: large and small arteries in the heart, lungs, brain, and intestines. CO^2 also plays the critical role in maintaining your acid-base balance (pH).

The optimum level of carbon dioxide is in the range of 40 to 45 millimetres of mercury (mmHg) or about 5% of exhaled CO^2. But, less than 3 people in 10 tested measure more than 30 mmHg! In other words, most people are unconsciously, habitually over breathing!

This condition can trigger symptoms and illnesses such as dizziness, insomnia, migraine, poor memory, lack of focus, loss of concentration, etc. Constriction (spasm) of micro-vessels in the heart results in various cardiac disorders, because muscle tissue, and other cells don't get enough oxygen.

The constriction of micro-vessels leads to increased peripheral resistance in the vessels, and results in increased arterial blood pressure. The heart must work harder, causing various symptoms. One may then provoke a crisis through some ordinary activity, or slightly increased stress.

In the case of asthma, the dynamics are the same: bronchioles constrict in response to lowered CO^2 levels resulting from over ventilation. A low level of CO^2 leads to acid-alkaline imbalance (alkalosis) of blood and tissues. This leads to developing of atherosclerosis, arthritis, and formation of 'stones', deposits, etc.

We can now understand the symptoms of breathlessness, shortness of breath, chest tightness and pressure, chest pain, feelings of suffocation, sweaty palms, cold hands, tingling of the skin, numbness, heart palpitations, irregular heartbeat, anxiety, apprehension, emotional outbursts, stress, tenseness, fatigue, weakness, exhaustion, dry mouth, nausea, light-headedness, dizziness, fainting, black-outs, blurred vision, confusion, disorientation, attention deficit, poor thinking, poor memory, poor concentration, impaired judgement and problem solving, reduced pain threshold, headaches, trembling, twitching, shivering, muscle stiffness, tension and spasms, and abdominal cramps. Many people experience the effects of over breathing without even realising it.

It turns out that periodic 'overdosing' of carbon dioxide (hypercapnia) is necessary for maintaining healthy physiology. This happens for example as a result of jogging or exercise, and it explains some of the natural benefits of 'aerobic' activities.

Have you ever thought why you feel the need to take a breath every few seconds? Is it because the content of oxygen in your blood drops? No! The blood is almost always 96%-98% saturated with oxygen. Our breathing is regulated, first and foremost, by the amount of CO^2 in the blood, not oxygen!

When your muscles work, they burn glucose. This process produces carbon dioxide. This CO^2 ends up in the blood stream and stimulates the respiratory system in order to remove it.

When blood circulates through lungs, it picks up inhaled oxygen. Molecules of oxygen bind to haemoglobin and are carried by the blood to all the tissues and organs of the body. There, the haemoglobin releases oxygen so the cells can use it. But guess what is necessary for oxygen to be released from the haemoglobin? Carbon Dioxide: CO^2! (that stuff everyone thinks is so bad!). If there's not enough carbon dioxide in your blood, no matter how much oxygen your blood might contain, this oxygen will not be released into your cells and tissues. With conscious breathing, you can adjust your CO^2 receptor to induce optimal chemistry. Carbon Dioxide is also a natural vasodilator. A vasodilator is a substance that directly influences smooth muscle fibres which make up the walls of the arteries and other blood vessels, and air passages as well. We can now see how higher levels of CO^2 result in better oxygenation of body tissues and cells. This in turn corrects or prevents several conditions related to hypertension, or dependent on vaso-constriction and tissue hypoxia. An optimal level of CO^2 in the blood is 6.5%

Breathing training can produce a significant and sustained reduction in blood pressure. With training, one can go from breathing 8 to 12 litres of air per minute, to 3 to 5 litres per minute (ideal is 2 to 4 litres per minute). With training, CO^2 in the blood can go from 3%-4%, to 5%-6% (ideal is 6.5%). Utilisation of Oxygen can go from 25%-40%, to 60%-70% (ideal is 70%-75%).

It is important to note that oxygen saturation of the blood in just about everyone, remains a constant 96%-98%, regardless of breathing rate, volume, etc. That means that 'getting oxygen into the blood' is not a major concern in breathing training. Getting that oxygen rich blood from the lungs to the cells is the major concern in training.

A large range of symptoms can accompany respiratory alkalosis (over-breathing): light-headedness, paraesthesia, muscle cramps, angina, nausea, confusion. Severe alkalaemia (respiratory and metabolic alkalosis) causes cerebral vaso-constriction, muscular tetany, and seizures, ventricular arrhythmias. Treatment can vary from paper bag breathing to sedation and intubation.

It is possible to over-ventilate when obstructed airways don't allow for rapid exhale. If rate and volume are too high, the lungs won't have time to deflate, and 'breath stacking' takes place: increased lung volumes and intrathoracic pressure that reduces blood return to the heart. Blood pressure can drop rapidly and dramatically resulting in cardiac arrest and death! Reducing the frequency and volume of ventilated breaths can avoid this.

Regular practice of Breath Awareness and Conscious Breathing can restore natural, healthy physiological and chemical states. It is not unusual for people to heal themselves of hypertension and any number of other illnesses in as little as a few weeks. The key is daily practice.

Did you know?
Mosquitoes are attracted not by your body heat, but by the carbon dioxide that you give off?

Exercise:
Postponing the Inhale (lengthening the pause after the exhale):
Today we are going to experiment with "Breath Holding". We all remember as children having contests to see how long we could hold our breath. This game has certain intuitive wisdom. Breath holding has many physical, psychological and emotional benefits. And being able to hold our breath for a time can come in very handy, for example when swimming (or when visiting certain public toilets!)

The natural physiological breathing pattern at rest is: inhale, exhale, pause... inhale, exhale, pause... inhale, exhale, pause...

When most people hold their breath, they hold it after the inhale and before the exhale. In other words, they postpone the exhale. But since a natural physiological pause already exists after the exhale, we are going to hold the breath at that point: in other words, we are going to postpone the inhale.

When you hold your breath, one of the things that happens is that carbon dioxide (CO^2) begins to build up in your system. This triggers many thoughts, feelings, sensations, and emotions. The longer you hold your breath, the stronger these triggers become. The urge to breathe becomes stronger and stronger, until finally it borders on panic, and you simply MUST breathe. A healthy person at rest should be able to manage a controlled pause of thirty seconds or more after the exhale, with no discomfort. However, many people begin to experience 'air hunger' and the feeling that they 'must' breathe after a pause of only five to ten seconds! The practice of lengthening the natural pause after the exhale is a very healthy and revealing exercise.

The point is to see where your comfort level is, and gradually increase the length of the comfortable pause after the exhale. The idea is to practice postponing the inhale... longer and longer... without experiencing any stress or strain or discomfort of any kind.

This is not about forcing yourself to turn blue, or trying to break the world record! This is about gently training your system to tolerate higher levels of carbon dioxide.
This has profound physiological, emotional, and psychological benefits because carbon dioxide is a volatile acid, and therefore it affects the pH balance in your body. Carbon dioxide also acts as a vasodilator, affecting the smooth muscles that form the walls of blood vessels, bronchial vessels, and your intestinal passages.

As CO^2 increases in your system, it causes micro-vessels to dilate (to open and expand). This sets the stage for oxygen delivery and transfer of nutrients and metabolic wastes to and from the organs, tissues, and cells.

This exercise is best done sitting.
Enjoy a normal inhale, and let the breath out naturally.
Then, without tensing any muscles... simply wait... don't breathe in.
During this pause, notice the feelings and sensations arising in your body... And notice your REACTIONS to these feelings and sensations. Relax into them.
Look, listen and feel inwardly as the urge to breathe gets stronger... Remain relaxed during this growing sense of urgency... And when the feelings begin to get too strong... simply let a natural inhale happen.
If you have to recover, that is if you find yourself gasping for air... or if you need to take several big breaths after the pause... it means that you have held your breath too long. After a few moments, try again, this time back off on the length of your pause... not holding the breath out as long.
Practicing this method several times per day (increasing the length of the pause by only 1 or 2 seconds every day or two), over the next several weeks, you can increase your controlled pause to a comfortable 30 to 45 seconds.
Many people around the world have healed their asthma using this method, and they have overcome anxiety attacks and panic disorders, as well as many other conditions. It is a very powerful Breath Therapy Exercise/Technique!

Good luck with your practice! Remember to be gentle and patient with your system. Absolutely no forcing or straining!