How to Breathe Correctly for Optimal Health, Mood, Learning & Performance | Huberman Lab Podcast

In this episode, I explain the biology of breathing (respiration), how it delivers oxygen and carbon dioxide to the cells and tissues of the body and how is best to breathe—nose versus mouth, fast versus slow, deliberately versus reflexively, etc., depending on your health and performance needs. I discuss the positive benefits of breathing properly for mood, to reduce psychological and physiological stress, to halt sleep apnea, and improve facial aesthetics and immune system function. I also compare what is known about the effects and effectiveness of different breathing techniques, including physiological sighs, box breathing and cyclic hyperventilation, "Wim Hof Method," Prāṇāyāma yogic breathing and more. I also describe how to breath to optimize learning, memory and reaction time and I explain breathing at high altitudes, why "overbreathing" is bad, and how to breathe specifically to relieve cramps and hiccups. Breathwork practices are zero-cost and require minimal time yet provide a unique and powerful avenue to improve overall quality of life that is grounded in clear physiology. Anyone interesting in improving their mental and physical health or performance in any endeavor ought to benefit from the information and tools in this episode.

#HubermanLab #Breathing #Science

Social & Website
Instagram: https://www.instagram.com/hubermanlab
Twitter: https://twitter.com/hubermanlab
Facebook: https://www.facebook.com/hubermanlab
TikTok: https://www.tiktok.com/@hubermanlab
LinkedIn: https://www.linkedin.com/in/andrew-huberman
Website: https://hubermanlab.com
Newsletter: https://hubermanlab.com/neural-network

Articles
Concentration of carbon dioxide, interstitial pH and synaptic transmission in hippocampal formation of the rat: https://bit.ly/3k3BG3y
Effects of voluntary hyperventilation on cortical sensory responses

Electroencephalographic and magnetoencephalographic studies: https://bit.ly/3k9rkyS
Brief structured respiration practices enhance mood and reduce physiological arousal: https://bit.ly/3KgN5rj
Breathing Rhythm and Pattern and Their Influence on Emotion: https://bit.ly/3XRxsda
Nasal Respiration Entrains Human Limbic Oscillations and Modulates Cognitive Function: https://bit.ly/3EgX1gr
Effect of breathwork on stress and mental health: A meta-analysis of randomised-controlled trials: https://go.nature.com/3XMKYi7

Books
Jaws: The Story of a Hidden Epidemic: https://amzn.to/3Yvloyo

Timestamps
00:00:00 Breathing
00:09:36 Respiration, Oxygen & Carbon Dioxide
00:18:18 Breathing Mechanics
00:31:23 Chemistry of Breathing, Hyperventilation
00:40:35 High Altitudes, Oxygen & Breathing
00:47:16 Tool: Sleep Apnea, Nasal Breathing
00:51:50 Brain Centers & Breathing Rhythm
00:57:23 Brain, Hyperventilation & "Over-breathing"
01:03:53 What is Healthy Breathing?
01:09:44 Tool: Train Healthy Breathing, Carbon Dioxide Tolerance Test & Box Breathing
01:22:39 Tool: Breathwork & Stress Reduction; Cyclic Sighing
01:33:56 Tool: Physiological Sighing & Exercise Side Cramp
01:39:16 Breathing & Heart Rate Variability
01:46:21 Tool: How to Stop Hiccups
01:51:17 Tool: Stress Management & Cyclic Hyperventilation, "Wim Hof Method"
01:57:11 Deliberate Cold Exposure & Breathing
01:59:54 Tool: Inhales & Learning; Exhales & Movement
02:09:15 Mouth vs. Nasal Breathing, Aesthetics

Title Card Photo Credit: Mike Blabac - https://www.blabacphoto.com

ANDREW HUBERMAN: Welcome to the Huberman Lab podcast, where we discuss science and science-based tools for everyday life. [MUSIC PLAYING] I'm Andrew Huberman, and I'm a professor of neurobiology and ophthalmology at Stanford School of Medicine. Today, we are discussing breathing. Now, breathing is something that we are all familiar with because, frankly, we are all doing it right now. And we do it during our waking states and while we are asleep. And most of us have probably heard that breathing is essential to life. We hear that we can survive without food for some period of time, maybe even up to a month or more, that we can't survive that long without water, but we could survive a few days without water, depending on how well hydrated we are when we go into that water deprivation and the heat of the environment we happen to be in, but that we cannot survive without breathing for more than a few minutes and that if we cease to breathe, that our brain and our bodily tissues will die. And, in fact, that is true. However, despite everybody's knowledge that breathing is essential to life, I don't think that most people realize just how important how we breathe is to our quality of life. And that includes our mental health, our physical health, and what we call performance, that is, our ability to tap into skills, either physical or cognitive, in ways that we would not be able to otherwise if we are not breathing correctly. So today, we are going to talk about what it is to breathe correctly, both at rest, during sleep, in order to reduce our levels of stress, in order to wake up or to become more alert deliberately, and many, many other things, including how to stop hiccuping. This is one of the most searched for topics on the internet. Today, I will teach you the one method that is actually linked to science. No, it does not involve drinking a glass of water backwards from the opposite side of the cup or holding your breath in any kind of esoteric way. It actually relates to the neural mechanisms, that is, the brain to body connections that cause the hiccup. Hiccup is a spasm of that neural circuit, and I'll teach you how to turn off that neural circuit in one try. And that's not a technique I developed. It's a technique that's actually been known about for several centuries. And we now know the underlying mechanism. So today's discussion will give to you many tools that you can apply. All of these tools are, of course, behavioral tools. They're completely zero cost. And in telling you how those tools work, you'll learn a lot about how the breathing, a.k.a. the respiratory, system, works and how it interfaces with the other organs and tissues of the body, in particular the brain. In fact, one of the most important things to understand about breathing right here at the outset is that breathing is unique among brain and bodily functions in that it lies at the interface between our conscious and our subconscious behavior. And it represents a bridge literally in the brain between the conscious and the subconscious. What do I mean by that? Well, breathing does not require that we pay attention to our breathing or that we are even aware that we are breathing. It will just carry on in the background either normally or abnormally, and I'll teach you what normal and abnormal breathing is in a little bit. However, breathing is unique among brain and bodily functions in that at any moment, we can consciously take control of how we breathe. This is an absolutely spectacular and highly unusual feature of brain function. For instance, your digestion is carrying on in the background right now whether or not you've had food recently or not. But you can't simply control your digestion by thinking about it in a particular way. In fact, most people can't even control their thinking by trying to control their thinking. That actually takes some practice. It can be done-- a topic for a future episode. However, breathing is unique. Breathing will carry on involuntarily, subconsciously in the background, as I said before. But if, at any moment, you want to hold your breath or inhale more deeply or vigorously or exhale longer than you inhale, you can do that. Very few, if any, other neural circuits in your brain and body allow that level of control. And it turns out that level of control is not an accident. It has been hypothesized that by controlling breathing, the brain is actually attempting to control its own state of mind. Now, the way this was originally stated in a scientific research paper was a little bit different. It was a little bit physiological. The statement was, "The brain, by regulating breathing, controls its own excitability." Excitability in the context of neurobiology is how able the brain is to take in new information or not, how able the brain is or not to turn itself off to go to sleep and to regulate its own levels of anxiety, focus, et cetera. If that seems a little bit abstract, I'll make it simple for you. By changing your pattern of breathing, you can very quickly change what your brain is capable of doing. In fact, a little bit later, I'll tell you that while you inhale, you are far better at learning and remembering information than during an exhale. And it is a very significant difference. Does that mean you should only inhale and not exhale? No, of course not. I'll teach you how to breathe for the sake of learning and memory as well as for physical performance and a number of other things. So hopefully I've been able to highlight for you the importance of breathing not just for life, because, yes, breathing is essential for life, but that the subtleties of how we breathe, the duration and intensity of our inhales and our exhales, how long we hold our breath between inhales and exhales, very critically defines our state of mind and our state of body, what we are able to do and what we are not able to do. And the great news is we can control our breathing and, in doing so, control our mental health, physical health, and performance.

00:09:36 Respiration, Oxygen & Carbon Dioxide

Let's talk about breathing. And, of course, we breathe in order to bring oxygen into the body. But we also breathe to remove certain things from our body, in particular carbon dioxide. So the main players in today's discussion are going to be oxygen and carbon dioxide. Now, a common misconception is that oxygen is good and carbon dioxide is bad. That's simply not the case. Let's just take a step back from that statement, and let's think about this. When we breathe in, we are largely breathing in air in order to bring oxygen into our body. And we can just stop right there and say, why do we breathe at all? Why can't we just get oxygen from the world around us? Well, it's because oxygen can't diffuse through our skin into the deeper cells of our body. Other single cell and very simple organisms can actually bring oxygen into their system without the need to breathe. But we have to breathe in order to bring oxygen to the cells that reside deep in our body. In particular, our brain cells, which are the most metabolically active cells in our body, require a lot of oxygen. And those brain cells are sitting, of course, in the brain, which is encased in the cranial vault, the skull. And so oxygen can't simply pass to those cells. So we need to have a system that will deliver oxygen to those cells. We also need a system, which turns out to be the breathing or respiratory system, that can offload or remove the gas that we call carbon dioxide, not because carbon dioxide is bad but because too much of it in our system is not good. In fact, much of today's discussion will also center around the common misconception that carbon dioxide is something that we want to get rid of. You don't want to get rid of too much carbon dioxide or else you can't actually get oxygen to the cells and tissues of your body in an efficient way. So you need oxygen and you need carbon dioxide in your body. You also need to be able to offload or remove carbon dioxide and bring in oxygen in the correct ratios so that you can perform the kind of mental functions and physical functions that you want to. So if we just dial out even further, we say, what are the key components of breathing? What are the elements within the body that allow us to bring oxygen to the tissues and cells as is required and remove carbon dioxide from the body as is required and yet keep enough carbon dioxide around in order to allow oxygen to do its thing? Well, that breathing or respiratory apparatus has two major components, and I'm going to just briefly describe those. And as I do this, I really want to highlight the fact that any time you're thinking about biology and physiology in particular, whether or not it's about the brain or the liver or the gut microbiome, it's useful to categorize things either as mechanical mechanisms or chemical mechanisms. What do I mean by that? Well, let's just take the analogy of hunger. There are mechanical mechanisms that tell us when we should eat. For instance, you have neurons, nerve cells in your gut that signal how stretched or nonstretched the walls of your stomach are, how full or how empty your gut is, and send that information to the brain to make you feel to some extent hungry or not hungry. In general, when our stomach is very full and especially if it's very distended, even with liquid, it suppresses our hunger. Whereas when our stomach is devoid of that mechanical pressure, especially for a number of hours, it tends to trigger hunger by signaling via neurons to the brain. In addition, there are chemical signals that go from the gut to the brain. For instance, we have neurons in our gut that can detect the presence of amino acids from proteins that we eat, fatty acids from the foods that we eat, the lipids, and sugars, different forms of carbohydrate. The neurons in our gut are paying attention to or respond to how much amino acid, fatty acid, and carbohydrate is in our gut and sends signals to the brain to either stimulate or suppress hunger. So those are chemical signals that are being passed from gut to brain, and they work in parallel with the mechanical signals. And this idea of "in parallel with," again, is a very common theme in biology, especially neuroscience. The term parallel pathways refers to the fact that any time there's a critical bodily function, it's very unlikely that just one type of information, like just mechanical information, is going to be used. / Almost always, it's going to be mechanical and chemical information. I could pick a number of other examples. For instance, if you want to avoid damaging your skin or other tissues of your body, which is essential to life, well, then you have mechanical information about, for instance, whether or not something is pinching or ready to pierce your skin. That's mechanical information. It's sent via specific neurons up to the brain to signal a retraction reflex if you move your limb away from wherever that intense pressure is coming. You also have chemical sensing in your skin, the presence of things that elicit a burn or that elicit itch or that elicit extreme cold. All of that chemical information is being signaled up to the brain as well in parallel. So parallel pathways is a common theme. So when we're thinking about the respiration, a.k.a. the breathing, system, we also need to look at the mechanical system. What are the different components of the nose, the mouth, the lungs, et cetera, that allow oxygen to be brought in and carbon dioxide to be removed from the body but not too much carbon dioxide removed to allow breathing to work as efficiently and as optimally as possible? And then we also need to look at the chemical systems of the lungs, the bloodstream, and how different cells use oxygen and carbon dioxide in order to understand that as well. If you can understand the mechanical and chemical aspects of breathing, even just at a top contour, well, then the various tools that I discuss during today's episode, such as the ability to calm yourself down most quickly by doing what's called a physiological sigh-- I'll go into this in more detail in a little bit, but this is two very deep inhales through the nose. So the first one is a long inhale [INHALES DEEPLY],, and then the second one after that is [INHALES SHARPLY] a quick, sharp inhale to maximally inflate your lungs, followed by a full exhale through the mouth to lungs completely empty. So it's big inhale through the nose, then short inhale through the nose immediately after that in order to maximally inflate the lungs, and then a long exhale through the mouth until your lungs are empty. You will understand why that particular pattern of breathing and not simply one inhale or not simply an inhale through the nose and an exhale through the nose as well is optimal for reducing your stress quickly. That double inhale through the nose followed by a long exhale through the mouth works to reduce your levels of stress and lower your levels of so-called autonomic arousal very fast in real time. And it works better than any other known approach. It's not a hack. This is actually something that your body has specific neural circuits to do, and it actually performs during sleep on a regular basis and even throughout the day, and that you can perform voluntarily. And it works so well to reduce stress very quickly not because it brings in the maximum amount of oxygen and removes the maximum amount of carbon dioxide but, rather, because it optimally balances oxygen and carbon dioxide. If you understand the mechanical and chemical aspects of breathing, then you will understand exactly why that particular pattern of breathing, the so-called physiological sigh, is the most efficient way to rapidly reduce stress in real time. If you can understand the mechanical and chemical aspects of breathing, you will also understand why most people are overbreathing. That is, they're breathing too often, even if they're breathing in a shallow manner. They're breathing too often. And they are blowing off or removing too much carbon dioxide. And if you understand that carbon dioxide is critical for the way that oxygen is delivered from the bloodstream to the tissues of the body, including the brain, well, then it will make very good sense as to why people who are breathing too much don't actually experience all the effects of elevated oxygen, but, rather, they're putting their body into what's called a hypoxic state. They're not getting enough oxygen to the tissues of their body, in particular their brain. And this is true not just for people who are obese or who suffer from sleep apnea, although that's certainly the case, but for people that have, believe it or not, certain personality types. We'll talk about breathing and personality type and actually how breathing has been shown to alter personality. That's right. Breathing can alter personality in positive ways that allow anyone to show up to the various social and nonsocial endeavors of their life with more calm, more focus, alertness, and improve their overall health. OK, so let's talk about the mechanical components of breathing. It's really quite simple. You've got your nose, obviously, and you've got your mouth.

00:18:18 Breathing Mechanics

And a little bit later, we'll talk about the incredible advantages of being a nasal breather most of the time but also the incredible advantages of using your mouth to breathe both for inhales and exhales during particular types of endeavors. And we'll get back to that a little later. But for the meantime, the only two ways to bring air into your system are through your nose and through your mouth. We also have the larynx, which is a rigid tissue or pipe that brings the air from the nose and mouth down to the lungs. Now, that word rigid is really important here because what we will soon learn is that your lungs basically act like a pump. You sort of know this already. But these are two big bags basically that can fill with air or that can squeeze air out. Now, what most people don't realize is that the lungs are not just too big bags of air. Your lungs are actually too big bags of air that inside of them have hundreds of millions of little sacs that are called the alveoli of the lungs. And by having those hundreds of millions of little sacs, you increase the surface area of the lungs. And by increasing the surface area, you allow more oxygen to pass from the air in your lungs into the bloodstream than if you didn't have those sacs. And you allow more carbon dioxide to move from the bloodstream into those sacs of the lungs, and then when you exhale, the carbon dioxide can be removed. So those little sacs we call alveoli of the lungs are an important part of the mechanical aspect of breathing we'll get to a little bit later. So at a first pass, the mechanical aspects of breathing are really straightforward. You can breathe through your nose. You can through your mouth. It goes down through the larynx. I told you the larynx is a rigid pipe. The lungs are not rigid. They can expand and they can contract like a pump to bring in air or to expel air. Keep in mind that the lungs do not have any muscles themselves. So we need muscles that can either squeeze the lungs or that will allow the lungs to expand. And there are two general groups of muscles that do that, and they are the diaphragm and the so-called intercostal muscles. The diaphragm is a thin muscle that sits below the lungs and above the liver. And when we inhale, provided that we are using what's called diaphragmatic breathing, that diaphragm contracts. And when it contracts, it moves down, which allows more space for the lungs to inflate with air. Now, the intercostal muscles are the muscles between our ribs. A number of people probably don't realize this. But your ribs, of course, are bone, but in between those bones, you have muscles. And the intercostal muscles, when you inhale, contract, and that allows your rib cage to move up and to expand a bit. And I think, again, people probably don't realize that your ribs are not fixed in place. They can actually get further and closer apart from one another. So when you inhale, your rib cage actually moves up. Sometimes the shoulders will move up as well. And that's because those intercostal muscles are contracting. Now, muscles can't move on their own. They are controlled by nerves. So we've got the nose, the mouth, the larynx, and the lungs. The lungs have all those little alveoli in them. And as I told you, we've got the diaphragm as a muscle to move the lungs, and we have the intercostal muscles to move the ribs, which can allow the lungs to expand. Again, we're just on the mechanical components of breathing. But because muscles can't move themselves, you should be asking, what moves the muscles? And it's really nerves that control muscles. So whether or not you're contracting your biceps or you're walking and you're contracting your quadriceps and your hamstrings and your calf muscles, it's neurons, nerve cells that control that. There's a specialized nerve called the phrenic nerve, P-H-R-E-N-I-C, phrenic nerve, that comes out of the neck. And when I say it comes out of the neck, what I mean is that there are little neurons that reside in the brainstem, in the back of your brain, and they send little wires that we call axons down and out of the neck. They go close to the heart and a little bit behind it. And they go down, and they form synapses. That is, they form connections with the diaphragm. And when those neurons release neurotransmitters, which are little chemicals, the diaphragm contracts, and it moves down. So we say that the phrenic nerve is a motor nerve. It's designed to move muscle. However, the phrenic nerve, like a few other nerves in the body, is interesting in that it has not just motor nerves in there, neurons that control the contraction of muscles. It also can sense things, has sensory neurons. So it also sends connections down to the diaphragm and actually down deep into the diaphragm and close to the liver. And note that I said liver twice now already, and we're going to get back to this later when we talk about physical movement and cramps of the body. Those sensory neurons dive deep into the diaphragm. And then they go back up to the brain, and they allow you to sense where the diaphragm is. So they're giving information about where the diaphragm is in your body. Now, most of the time, you're not paying attention to this. But right now, you can actually try this. And I would encourage you to do this. Diaphragmatic breathing is, in many ways, the ideal way to breathe and that it's the most efficient way to breathe. We'll talk about what we mean exactly when we say breathing efficiency later. But the diaphragm is designed to allow the lungs to expand or to contract the lungs, to bring air into the body or to remove carbon dioxide from the body. And if you want to know whether or not you're using diaphragmatic breathing, it's very simple. If you inhale-- probably best to do this through the nose, but you could do it through the mouth. If you inhale and your belly moves outward on the inhale, well, then that phrenic nerve is controlling your diaphragm properly. And then when you exhale, your belly should go in just a little bit. That's diaphragmatic breathing. Now, diaphragmatic breathing is talked about in the context of yoga. It's often talked about as a way to calm down and so on. But diaphragmatic breathing is just one mode by which your brain and the phrenic nerve can control muscle, the diaphragm, to control the mechanical aspects of the lungs to bring in air and expel air. As I mentioned before, you also have these muscles between your ribs or the intercostal muscles. And there's a separate set of nerves that allow those muscles to contract and for your rib cage to expand in order to create more room for your lungs to get larger and fill with air or for your rib cage to contract a bit when those muscles relax in order to expel air. I'd like to go on record by saying that there is no rule that diaphragmatic breathing is better than breathing where your rib cage moves. This is a common misconception. People say, oh, if your shoulders are going up and down and your rib cage is moving while you're breathing, well, then you're not breathing right. And if your belly goes out and the rest of your body is still while you breathe, well, then you're breathing correctly. I know of zero-- in fact, zero minus one data to support that statement. You have multiple parallel mechanisms to control the mechanics of your lungs and for breathing. And when you're exerting yourself very hard, you tend to use both the intercostal muscles and your rib cage moving as well as your diaphragm in order to bring in a lot of oxygen and to offload a lot of carbon dioxide. And when you're calmer, frankly, you could use diaphragmatic breathing or you could use rib cage type breathing in order to bring enough oxygen into your system. There's no real data showing that diaphragmatic breathing is somehow better or worse. However, being able to mechanically control those independently or to combine them and use them together is of tremendous power toward regulating your mental and physical states. And we'll talk about how to do that a little bit later. For right now, please understand that you have these different mechanical components that allow you to bring oxygen into your system and to expel air and to thereby offload carbon dioxide from your system. Again, we haven't talked about the gas exchange of carbon dioxide and oxygen and how that's happening in the bloodstream. We'll talk about that next. But the basic mechanical components are pretty simple. Once again, just to review, it's nose, mouth, larynx, lungs, alveoli within the lungs, and then those two muscles, the diaphragm and the intercostal muscles of the ribs. And one thing I failed to mention is why it's so important that that larynx be rigid, that it's a tube that is very rigid. And the reason for that is that unlike the lungs, which you want to act as sort of a bellow pump where you can deflate it and inflate it in order to move air in and out, the larynx needs to be rigid so that it doesn't collapse while you're bringing air in and out. You can imagine that if it was a very flimsy tube or the walls of the larynx were very flimsy and thin, well, then you can imagine breathing in very vigorously, and it would shut like a tube that suddenly flattens on itself, which would not be good. So the fact that the larynx is rigid is actually a very crucial part of this whole system. The other important aspect of this system as it relates to the mechanics of breathing is the fact that your nose and your mouth have different resistances to air. You can probably notice this right now if you were to, for instance, breathe in through your mouth [INHALES] and only through your mouth versus breathing through your nose [SNIFFS]. Some of you perhaps have a harder time breathing in through your nose. By the way, it's perfectly normal that one or the other nostril would be harder to breathe through or easier to breathe through and that switches across the day. It has to do with the flow of mucus and cerebrospinal fluid and intracranial pressure. Totally normal. Many people out there think they have a deviated septum who don't actually have a deviated septum. A little bit later, we'll talk about how to repair a deviated septum without surgery because that actually is possible in many, not all, cases and is immensely beneficial to do. But what we know is that breathing in through the nose is a little bit harder, and it's supposed to be a little bit harder. However, because it's a little bit harder because there's more resistance, as we say, you are actually able to draw more force into these mechanical aspects of the breathing apparatus and actually bring more air into your lungs. You can try this right now. Try breathing in through your mouth to maximally inflate your lungs and try and do it through mostly diaphragmatic breathing, just for sake of example. In other words, try and breathe in through your mouth. And as you do that, have your belly expand and maximally inflate your lungs. I'll do it right now with you so that we can do it together and I can prove to everyone that I'm just as deficient in this as you are. [INHALES] OK, so I can inflate my stomach doing that. But now try doing it with your nose, and please do exhale before you try doing it with your nose. With your nose, you're going to feel more resistance, but you'll notice that you can inflate it quite a bit further. [SNIFFS] And you'll feel your entire cavity, your belly and maybe even in your lower back, fill with some pressure. So the increased resistance actually allows you to draw more air into the system. This turns out to be very important. And it also wipes away a common misconception, which is if you're somebody who has challenges breathing in through your nose, that somehow you should avoid breathing in through your nose, actually, quite the opposite is true. And we can go a step further and say that if you have challenges breathing in through your nose, chances are that's because the increased resistance of breathing in through your nose, provided it's not completely occluded, is going to allow you to bring more oxygen into your system. This will turn out to be useful later when we explore different techniques, for instance, not just to calm down quickly but to elevate your energy quickly, to remove a cramp during exercise, and a number of other things that breathing can be used for that can be immensely useful for mental and physical challenges.

00:31:23 Chemistry of Breathing, Hyperventilation

So now let's talk about the chemical aspects of breathing. And the two major players in this discussion are oxygen, which all the cells and tissues of your body need, and carbon dioxide, which all the cells and tissues of your body need. In fact, carbon dioxide plays critical roles in delivering oxygen to your cells. And without carbon dioxide, you're not going to get enough oxygen to the cells and tissues of your body. That said, if carbon dioxide levels are too high, that is very problematic. In fact, one of the ways that one can reliably induce panic in anybody is to have them breathe air that contains too much carbon dioxide, so much so that for people that lack a so-called amygdala-- many of you have probably heard of the amygdala. This is a brain area that's associated with fear and threat detection. Even in people who completely lack amygdalas on both sides of the brain because they were removed because they had epileptic seizures there and, therefore, those people are completely unafraid of things that they ought to be afraid of like heights, poisonous snakes, any number of different things dangerous to humans, well, if those people breathe an excess amount of carbon dioxide, they immediately have a panic attack. What that tells us is that, again, there are parallel mechanisms, there's redundancy in the system to protect ourselves from having too much carbon dioxide in our system. So we need enough carbon dioxide and enough oxygen in our system but not too much. The way that's accomplished is, of course, we breathe in air. Our lungs inflate. And if you recall those little alveoli of the lungs, those little sacs, oxygen can actually move from the air into those little sacs and then from those little sacs into the vasculature-- the vasculature are the capillaries, the veins, and the arteries of the body-- because the walls of those little alveoli are exceedingly thin, and they have tons of little capillaries that go into them and are all around them. So this is amazing, right? There's oxygen literally passing from inside of these little sacs in our lungs because we inhaled the oxygen from the air into the bloodstream, and then that oxygen gets bound up by proteins in the blood, in particular hemoglobin. And hemoglobin then delivers oxygen to the various cells and tissues of the body. However, oxygen can't just hop on hemoglobin and cruise along with hemoglobin until it gets to, say, your brain and then hop off. It doesn't work that way. You require carbon dioxide in order to liberate oxygen from hemoglobin. Carbon dioxide has this incredible property of actually being able to change the shape of hemoglobin. Hemoglobin is shaped as a sort of a cage around oxygen molecules. And when it's in that cage shape, the oxygen can't be liberated. So you've got oxygen and hemoglobin bound to one another moving through your bloodstream. But if a tissue needs oxygen, there needs to be carbon dioxide present to open up that cage. And that's what carbon dioxide does. It allows that cage to change shape, and then the oxygen can be liberated and then can be delivered to the tissues, whether or not that's brain tissue or muscle tissue, so on and so forth. And so those are the major chemical components of breathing. There are a few other aspects related to the chemical components of breathing, such as the fact that carbon dioxide is strongly related to how acidic or how basic your body is in general. So for instance, if carbon dioxide levels go way down, your blood pH goes way up. That is, you become more alkaline. Now, for many people, the word pH and the whole concept of pH immediately starts to evoke anxiety in and of itself. pH is actually very simple. You want the body basically to be at a pH of about 7.4. There are some regions of your body, in particular along the gut, for which that number is importantly different in order for digestion to work properly. You've all heard of the gut microbiome, the little microbes that, provided you have enough of them and they're diverse enough, allow your brain and body to function optimally at the level of immune system, hormone system, brain, et cetera. Well, in the gut, you want the pH sometimes be slightly more acidic. Because when it's more acidic, the little microbiota flourish far more than if it were more basic. But basically, you want the rest of the body to be at about pH 7.4. If carbon dioxide levels go to low, the pH increases in a way that you might say, oh, well, that's bad, but that actually allows more oxygen to be available to the tissues of your body, at least temporarily. We'll talk about this a bit more later. If I'm losing any of you, just hang in there because we're almost done with this whole business of the mechanics and the chemistry of breathing, and then we can get into the tools and revisit some of this later to clean up any misunderstandings that may have arisen. But as we're talking about carbon dioxide over and over again and how key it is to have carbon dioxide and the problems with it going too high to low, you should probably be asking yourself, what actually makes carbon dioxide go too low? We know that we breathe in oxygen, and then it can pass from the lungs and the alveoli into the bloodstream and that we need carbon dioxide to liberate oxygen from the hemoglobin into the cells and tissues of the body. And we know that when we exhale-- well, actually, I haven't told you this yet. But you should know that when you exhale, carbon dioxide is actually taken from the bloodstream back into the alveoli of the lungs. And then when you exhale, it's expelled through your mouth or through your nose out into the world. So the way I just described all that-- inhale, bring in oxygen, exhale, expel carbon dioxide-- pretty straightforward, right? Indeed, it is. And it also tells you that were you to exhale a lot more or a lot more vigorously, you would expel more carbon dioxide.

And in fact, that's exactly the way it works. When you hyperventilate, of course, you are inhaling more than usual, but you are also exhaling more than usual. So you're, of course, bringing in more air and oxygen to your body. But you're also removing more carbon dioxide from your body than normal. Carbon dioxide, because of the ways that it regulates brain state-- in fact, the way in which it regulates the excitability, literally the ability of your neurons to engage electrically or not-- it can create states of panic and anxiety, which is why when you hyperventilate, you feel an increase in anxiety, or when you feel an increase in anxiety, you hyperventilate. It's a reciprocal relationship. In fact, I don't want anyone who has anxiety or who has panic attacks to try this now. But for most people, it's probably safe as long as you're not driving or doing something mechanical or operating machinery, that is. Probably safe to do 25 or 30 deep inhales and exhales. And you'll notice that by about breath 10, you'll start to feel tingly, and you'll probably feel a little bit more alert. And, again, if you have anxiety or panic attack tendencies, please don't do this. But you will feel an increase in so-called autonomic arousal, an increase in the activity of your overall sympathetic nervous system, which has nothing to do with sympathy, has everything to do with alertness. You'll actually deploy adrenaline from your adrenals. So I'll just do this now. You can try this now, again, provided you're in a safe place and you don't have anxiety or panic attack tendencies. You would just breathe in through your nose and out through your mouth. Remember, we're breathing in more and more vigorously, and we're exhaling more and more vigorously than we normally would. It goes something like this. [INHALING, EXHALING] Now, by breath 8 or 9 or 10, you'll notice that your body starts to heat up. That's due to a couple of things, mainly the release of adrenaline from your adrenals. I'm already feeling a little bit lightheaded. The lightheadedness is actually because your vasculature, the capillaries and veins and, to some extent, even the arteries of your body and particularly in your brain, are actually starting to constrict. So you're cutting off blood flow to the brain. Why? Well, because carbon dioxide actually is a vasodilator. Normally, it exists in your body to keep capillaries, veins, and arteries dilated to allow blood to pass through them. When you hyperventilate, sure, you're bringing in a lot of oxygen, which you think would make you more alert, and, indeed, it does. But you are also expelling a lot more carbon dioxide than you normally would. And that's causing some vasoconstriction, and you're going to start feeling tingly in the periphery, in your fingers and toes perhaps or your legs. You will also notice that you're feeling more alert in the brain but that you might start to feel a bit of anxiety. So hyperventilation, yes, brings in more oxygen, also removes more carbon dioxide. The removal of excess carbon dioxide puts you into a state that's called hypocapnic, hypoxia. Hypoxia is reduced levels of oxygen relative to normal. Hypocapnia is reduced levels of carbon dioxide relative to normal. And it is those reduced levels of carbon dioxide that are largely responsible for that elevation in energy and at the same time a feeling of a bit of anxiety, the construction of the microvasculature in the brain and body, and therefore the feelings of being kind of tingly and having kind of an urgency to move. OK, so by now, it should be clear that we need both oxygen and carbon dioxide. And across the course of this episode,

00:40:35 High Altitudes, Oxygen & Breathing

I will explain how to adjust those ratios of oxygen to carbon dioxide depending on what your immediate needs are and what you plan to do next, whether or not that's sleep or exercise or mental work, et cetera. Before going any further, however, there is something I want to touch on. Because even though not everyone will experience this, I think enough people experience it that it is of interest, and now's the right time to touch into what happens when you go up to a very high altitude, meaning why it's hard to breathe when you get up to high altitudes. So if you're close to sea level, you are getting out of the optimal balance of oxygen in the air you breathe. As you ascend in altitude-- so let's say you go to 6,000 feet or 10,000 or maybe even 11,000 feet above sea level. Or maybe you're one of those rare individuals that climbs Denali, or you climb Mount Everest, and you get up there, and you notice that most people are going to wear an oxygen mask. Why is it that you need an oxygen mask at those very high altitudes or when people do these very high altitude skydives that they need oxygen way up high? Well, a lot of people will say, oh, there's not much oxygen up there. The air is thinner. OK, well, perhaps a better way to think about it is that, remember when we were talking about the mechanical aspects of breathing and the fact that the lungs don't really move themselves, that they have the muscles, the diaphragm and the intercostal muscles to move them? Well, a lot of the reason why your lungs can fill so readily with air is that when you don't have much air in your lungs, there's very low air pressure in your lungs relative to outside you. So what we mean then is if you were to open up your mouth [INHALES] or your nose and breathe in, that is, breathe in through your nose or mouth, what's going to happen is air is going to move from high pressure to low pressure. So it's very easy to fill your lungs. Even though you need those muscles to move the various things around that allow your lungs to fill, the air is going to go from high pressure to low pressure. So [INHALES] for those of you listening, I just took a big inhale through my nose. And then when you exhale, you're basically taking the lungs from a state in which the pressure is really high in the lungs, high pressure, like a balloon that's full-- and the pressure in your lungs when your lungs are full is higher than the air outside. So it's pretty easy [EXHALES] to expel that air through the nose or mouth. When you're at high altitudes, the air pressure is lower. And so what happens is when the air pressure is lower outside your body and your lungs are not full of air, you don't have that really steep gradient of high pressure outside the body to low pressure inside your lungs. And so you actually have to put a lot more effort into breathing air into your lungs. You have to really exert a lot of force. You have to get the diaphragm, those intercostal muscles working really hard. You might even find that your shoulders are lifting with each breath [INHALES] because you really have to generate a lot of force to get enough air and oxygen into your lungs. Now, an important principle to understand is that in humans, and in some other species, but really what we're talking about now is humans, when you inhale, that's an active process. You really need to use those muscles of the intercostals and the diaphragm in order to inflate the lungs. But the whole process is made easier when air pressure outside your body is higher than it is in your lungs because then they're going to fill up really readily. Exhaling, at least for humans, is a passive thing. You just have to relax the diaphragm and relax the intercostals and let the rib cage kind of fall back to its original position. So inhaling is active, and exhaling is passive. And so what happens is if you're at a high altitude and the air pressure is very low, then you have to put a lot of energy into breathing air into your lungs to get an equivalent amount of oxygen into your lungs and then into the bloodstream. So that's why when you arrive at a high altitude location, for the first few days, you're going to feel lightheaded maybe a headache. You're also going to have more buildup of carbon dioxide in your system. And so the whole balance of oxygen and carbon dioxide is going to be disrupted. I mention all that because, yes, indeed, there are some changes in the atmospheric gases at high altitudes, and that can impact how much oxygen you can bring into your system, into your tissues. But I've heard many explanations of why it's hard to breathe or why you feel lousy at altitude. Well, you just discovered one reason, which is that you don't have that steep high pressure to low pressure gradient from the outside of the body into the inside of the body. The converse is also true. If you've been at altitude for a few days and you've had the opportunity to adjust-- a lot of athletes, for instance, will go train at altitude. It's hard for them in the first days or weeks, and then they get really good at training at altitude. There are a number of different adaptations that occur in terms of the amount of oxygen that can be carried in the blood by hemoglobin and the interactions between carbon dioxide and hemoglobin and oxygen that allow more oxygen to be delivered to the tissues, such that, at altitude, you can function just normally. But if you then move very quickly from altitude-- say, you've been training at 8,000 feet or 10,000 feet. You've been hiking up at that high level, and you've adapted, and you come down to sea level. Well, for about two to five days, you're going to feel like an absolute beast. You're going to be able to essentially deliver far more oxygen to your muscles per breath. In part, that is because of the way that the hemoglobin and the oxygen that it's carrying has been altered when you were at high altitude. But it's also because when you were at that high altitude, those intercostal muscles and those diaphragms got trained up quite a bit and allowed you to generate more air volume for every breath. In other words, those muscles got stronger, and you got more efficient at driving the phrenic nerve consciously to [INHALES] really breathe in a lot of oxygen so you don't feel lightheaded, headache, et cetera. OK, so that's a little bit of an aside. But it's an important aside, I believe, because, A, it answers a question a lot of people ask and they a lot of people wonder about and, B, because it incorporates both the mechanical aspects of breathing and the chemical aspects of breathing. I realize it's a little bit of a unusual circumstance. But now if anyone asks you why it's hard to breathe at altitude, you know it has to do with this lack of a high pressure to low pressure gradient across the body and with the atmosphere outside you. It's also an opportunity for me to say that if you do find yourself at altitude and you have a headache or you're feeling like you just can't catch your breath, spending some time really consciously trying to draw in larger breaths of air, as much as that might seem fatiguing and you'll be short of breath, it will allow you to adapt more quickly. And a little bit later in the episode, we'll touch on a few methods, including deliberate hyperventilation combined with some breath holds, that can allow you to deliver more oxygen to the cells immediately upon arriving at altitude so you don't get quite as much headache, disorientation, and so on. So leaving breathing at altitude aside let's all come back down to the same conceptual level.

00:47:16 Tool: Sleep Apnea, Nasal Breathing

We can ask ourselves, for instance, what is healthy breathing, and what is unhealthy breathing? And the first place we want to tackle this is within the context of sleep. So when we go to sleep at night, we continue to breathe. That's no surprise. If we didn't, we would die during sleep. However, there is a large fraction of the population that underbreathes during sleep. They're not taking deep enough or frequent enough breaths. And therefore, they are experiencing what's called sleep apnea. They are becoming hypoxic, hypo-oxic. There's less oxygen being brought into their system than is necessary. People that are carrying excess weight, either fat weight or muscle weight or both, are more prone to nighttime sleep apnea. However, there are a lot of people who are not overweight who also experience sleep apnea. How do you know if you're experiencing sleep apnea? Well, first of all, excessive daytime sleepiness and excessive daytime anxiety combined with daytime sleepiness is one sign that you might be suffering from sleep apnea. The other thing is if you happen to snore, it's very likely that you are experiencing sleep apnea. And I should mention that sleep apnea is a very serious health concern. It greatly increases the probability of a cardiovascular event, heart attack, stroke. It is a precursor or sometimes the direct cause of sexual dysfunction in males and females. Cognitive dysfunction during the daytime. It can exacerbate the effects of dementia, whether or not it's age-related dementia of the normal sort or Alzheimer's type dementia, which is an acceleration of age-related cognitive decline. If you're somebody who has had a traumatic brain injury, if you're experiencing a lot of stress, sleep apnea is going to greatly disrupt the amount of oxygen brought in to your brain and body during sleep and is going to lead to a number of nighttime and daytime issues. So it's something that really needs to be addressed. And we'll get into this a bit more later. But since I raised it as a problem, I do want to raise the solution. One of the major treatments for sleep apnea is that people will get a CPAP device, which is this face mask and a machine that they'll sleep with. And while those can be very effective, not everyone needs a CPAP. One of the more common methods nowadays that's being used to treat sleep apnea, which is purely behavioral, an intervention, and is essentially zero cost, is that people are starting to shift deliberately to nasal breathing during sleep because of the additional resistance of nasal breathing and because of the fact that there's far less tendency if any, excuse me, to snore when nasal breathing. Taping the mouth shut using medical tape prior to sleep-- excuse me. Putting medical tape on the mouth prior to going to sleep and then sleeping all night with medical tape on the mouth is one way that people can learn to nasal breathe during sleep and can greatly offset a lot of sleep apnea, snoring, and sleep-related issues (Mouth Tape). A number of people don't want to or don't feel safe putting medical tape on their mouth prior to sleep. For some reason, they think they're going to suffocate. But, of course, you would wake up if you start to run out of air at any moment. So that's not so much a concern(Mouth Tape). But what they'll do is they will start to use pure nasal breathing during any type of exercise or even just for some period of time walking during the day or while working. And, again, later, we'll get into the enormous benefits of shifting to pure nasal breathing when not exercising hard, meaning at a rate that you could normally hold a conversation-- although if you're pure nasal breathing, you won't be holding that conversation-- or when simply doing work or any number of things that are of low intensity. You can train your system to become a better nasal breather during the daytime through these deliberate actions of taping the mouth shut or just being conscious of keeping your mouth shut. And that, in addition to having a number of positive health and aesthetic effects during the daytime, is known to also transfer to nighttime breathing patterns and allow people to become nasal breathers as opposed to mouth breathers during sleep and to snore less and to have less sleep apnea. Again, if you have severe sleep apnea, you probably do need to check out a CPAP. You should talk to your physician. But for people who have minor sleep apnea or sleep apnea that's starting to take hold, these other methods of shifting to becoming a nasal breather are going to be far more beneficial and far more cost effective than going all the way to the CPAP, which, by the way, doesn't really teach you how to breathe properly as much as it does adjust the airflow going into your system. That's an important point, that when you shift from mouth to nasal breathing during sleep (Nasal Strips), you're actually learning and training your system to breathe properly. And when I say learning and training your system to breathe properly, what do I mean? Let's put some scientific and mechanistic meat on that. (Nasal Strips)

00:51:50 Brain Centers & Breathing Rhythm

We already talked about the phrenic nerve, this nerve that innervates the diaphragm and that allows for the lungs to fill up because of the movement of the diaphragm. What we didn't talk about, however, were the brain centers that actually control the phrenic nerve and control breathing. Knowing about these two brain areas and what they do is extremely important, not just for understanding the content of this episode but for understanding all of the tools that we'll discuss and, indeed, your general health as it relates to respiration. So there are basically two areas of the brain that control breathing. The first is called the pre-Botzinger complex. You don't have to worry about the name so much. Just know that it was named after a bottle of wine and that it was discovered by the great Jack Feldman, who's a professor of neuroscience at the University of California, Los Angeles. This is one of the most fundamental discoveries in all of neuroscience in the last hundred years or more because this brain area that Jack and his colleagues discovered controls all aspects of breathing that are rhythmic, that is, when inhales follow exhales follow inhales follow exhales. That's all controlled by a small set of neurons in this brainstem area, so around the region of the neck, called the pre-Botzinger complex. And we really owe a debt of gratitude to Jack and his colleagues for discovering that area because it's involved in everything from breathing when we're asleep to breathing when we're not thinking about our breathing. It may have a role-- that is, when its function is disrupted, it may cause things like sudden infant death syndrome. Believe it or not, it can explain in large part many of the deaths related to the opioid crisis because exogenous opioids like fentanyl and other sorts of drugs, which are opioids obviously, bind to opioid receptors on that structure and shut it down. Now, keep in mind these neurons are designed to be incredibly robust and are designed to fire inhale, exhale, inhale, exhale no matter if we're awake or aware, unaware or asleep to keep us alive. Exogenous opioids like fentanyl and drugs that are similar to that can shut down that structure because it's rich with these opioid receptors. So it binds to that, and it shuts off the pre-Botzinger complex, which is the major cause of death of people who die from opioid overdoses. I think a lot of people don't realize that. They think, oh, the opioids must shut off the brain or shut down the heart. No, it shuts down breathing. So Jack's discovery no doubt will lead to some important things as it relates to addiction, and hopefully I think we frankly can expect that it's also going to eventually lead to ways to prevent death in people using opioids or other types of drugs, maybe by blocking opioid receptors in pre-Botzinger complex using things like naltrexone, et cetera. In any event, pre-Botzinger complex is controlling inhale, exhale, inhale, exhale patterns of breathing. The other brain center controlling breathing, again, through the phrenic nerve-- it all converges and goes out through the phrenic nerve in these intercostal muscles-- is the so-called parafacial nucleus. And the parafacial nucleus is involved in patterns of breathing where there is not an inhale followed by exhale, inhale followed by exhale-- that is, it's not rhythmic, one than the other-- but, rather, where there is a doubling up of inhales or a doubling up of exhales or a deliberate pause in breathing, so inhale, pause, exhale, pause, inhale, pause, exhale, pause, this sort of thing. A little bit later, we'll talk about a pattern of breathing called box breathing, which has very specific and useful applications, in particular for adjusting anxiety. And in that case, it involves going from rhythmic breathing of inhale, inhale, inhale, exhale, that is, relying on the pre-Botzinger complex neurons, to reliance on the parafacial nucleus neurons and box breathing, just to give away what's probably already obvious, as you inhale, hold, exhale, hold, and repeat. And that pattern of breathing, even though it's rhythmic in nature because inhales precede exhales precede inhales and so on, there's a deliberate breath hold inserted there. So anytime we're taking conscious control of our breathing, the parafacial nucleus is getting involved. Now, you don't have to assume that the parafacial nucleus is the only way in which we take conscious control of our breathing. We can also take control of the pre-Botzinger complex. You can do that right now. So for instance, you are breathing in some specific pattern now that, unless you're speaking or eating, no doubt is going to involve inhales followed by exhales. But you could, for instance, decide that, yes, inhales are active and exhales are passive. But now you're going to make the exhales active as well. So rather than just inhale and then let your lungs deflate, you could inhale [INHALES] and then force the air out. [EXHALES] That's going to represent a conscious taking over of control of the pre-Botzinger complex. And so the reason I'm giving this mechanistic detail is, A, it's super important if you want to understand all the tools related to breathing. B, it's actually a pretty simple system. Even though the areas have fancy names like pre-Botzinger or parafacial, it's pretty straightforward. You have one area that controls rhythmic breathing-- inhale follows exhales-- and the other area which gets involved in breathing any time you start doubling up on inhales or exhales. In fact, the parafacial nucleus is the one that you're relying on while you speak in order to make sure that you still get enough oxygen. It's also the one that you will use if you incorporate the physiological sigh or box breathing. And, frankly, most of the time, you're using both of these circuits or these brain systems, parafacial and pre-Botzinger, in parallel. Again, biology loves parallel systems, especially for things that are so critical that if we didn't do them, we would die, like breathing. And so it makes sense that we have two different brain structures that control this. So now you have an understanding of the mechanical control of breathing, that is, the different parts within the parts list that are involved in breathing,

00:57:23 Brain, Hyperventilation & “Over-breathing” everything from nose to mouth to alveoli, the lungs, et cetera, and the muscles involved in moving the lungs. You understand, I like to think, a bit about bringing oxygen in and removing carbon dioxide but not so much carbon dioxide that you can't actually use the oxygen that you have. And you know about two brain centers, one controlling rhythmic breathing and one that controls nonrhythmic breathing. I want to repeat something that I said a little bit earlier as well, which is that breathing is incredible because it represents the interface between conscious and subconscious control over your not just body, not just your lungs, but that how you breathe influences your brain state. So by using your brain consciously to control your breathing, you are using your brain to control your brain. The best way I've ever heard this described was from a beautiful, I should say now classic paper in The Journal of Physiology, published in 1988 from Balestrino and Somjen, where the final line of their summary intro states, "The brain, by regulating breathing, controls its own excitability." And just to remind those of you that don't remember what excitability is, excitability is the threshold at which a given neuron, nerve cell can be active or not. So when we breathe a certain way, the neurons of our brain are more likely to get engaged. They're more likely to be active. And when we breathe in other ways, our brain becomes harder to activate. Its excitability is reduced. Now, you might think excitability is a great thing. You always want your brain to be excitable. But that's actually not the case. And, in fact, that very statement that Balestrino and Somjen made led to a number of other investigations that were really important in defining how if people overbreathe, that is, if they hyperventilate, at rest, they expel, that is, they exhale too much carbon dioxide, what that classic paper by Balestrino and Somjen led to was a number of different investigations in humans looking at how different patterns of breathing impact the overall state of the brain and the ability of the brain to respond to certain what are called sensory stimuli. Keep in mind that your brain is always active. The neurons are firing at low level, low level, low level. But when you see something or hear something, or you want to focus on something, or you want to exercise or really listen to something or learn, certain circuits in your brain need to be more active than everything else. That is, there needs to be really high what's called signal to noise. There's always a lot of noise and chatter in the background, just like the chatter at a cocktail party or at a stadium event. In order to really pay attention, focus, learn, all the incredible things that the brain can do, you need that signal to get above the noise. There's a beautiful paper that asks, how does the pattern of breathing, in particular, how does overbreathing, change the patterns of activity in the brain? This is a paper entitled "Effects of Voluntary Hyperventilation on Cortical Sensory Responses." And I will provide a link to the study in the show note captions. It's a somewhat complicated paper if you look at all the detailed analyzes. However, the takeaway from this paper is exquisitely simple and I also believe incredibly important. Basically, what it showed is that when people hyperventilate, they expel, that is, they exhale more carbon dioxide than they would normally. So they become what's called hypocapnic, OK? Carbon dioxide levels are low in the blood. And over a short period of time, they become low in the tissues of the body. When that carbon dioxide level drops low, you would say, OK, well, you're still bringing in a lot of oxygen, because these people are hyperventilating. So they should feel really alert. And, indeed, that's what happens. The people feel very alert. However, because they're not bringing enough carbon dioxide in or, rather, the proper way to say it would be because they're overbreathing, exhaling too much, they are not retaining or keeping in enough carbon dioxide. Well, then that lack of carbon dioxide means that the oxygen that they are breathing in can't be liberated from the hemoglobin, can't get to the brain. And what they observe is about a 30% to 40% reduction in the amount of oxygen that's being delivered to the brain. And the reduction in carbon dioxide also prevents some of the normal patterns of vasodilation, the dilating, the opening up of the capillaries, so, again, less blood flow. But most importantly, as it's shown in this paper, the brain overall becomes hyperexcitable. It's as if it's being starved of oxygen and blood flow. And all the neurons in a very nonspecific way start increasing their firing levels. So the background activity is getting louder and louder. It's like the rumble or the noise of a crowd at a stadium. And as a consequence, the sensory input from a sound or from a touch or from some other event in the world doesn't get above the noise. What this means is that when we hyperventilate, because we aren't retaining enough carbon dioxide, we are not getting enough oxygen to the tissues that need oxygen. And as a consequence of that, the brain becomes hyperexcitable. We actually know that there's an increase in anxiety. And we become less good, less efficient at detecting things in our environment. So we're not processing information as well at all. The noise goes up, and the signal goes down. Again, incredibly important set of findings. I should also mention that hyperventilation is one way that, in the laboratory anyway or in neurosurgery units for some time, physicians would evoke seizure in seizure-prone patients. The reason that works is exactly the explanation I just gave you. Seizure is a excitability of the brain, not enough inhibition or suppression of the overall circuitry. So you get these waves or these storms of electrical activity. Low levels of carbon dioxide in the brain because of low levels of carbon dioxide in the blood are one of the major triggers for seizures. Now, I realize that most people listening to this are not epileptic. But nonetheless, this brings us all back to this question of what is normal healthy breathing. As I mentioned before, normal healthy breathing

01:03:53 What is Healthy Breathing?

is breathing about six liters of air per minute. But of course, most of us don't think in terms of liters of air, and we're not going to measure our lung capacity, at least most of us aren't going to do that. Basically, if you are taking relatively shallow breaths and you're just sitting there working or maybe even walking slowly, again, not talking or engaging in any kind of speech or eating, chances are six liters of air per minute is about 12 shallowish breaths. And when I say shallow, I don't mean breathing [INHALES SHALLOWLY] like a little bunny rabbit or something like that. I just mean casually breathing in out, in out. The studies that have explored the breathing patterns in large populations of individuals who are not suffering necessarily from any one specific ailment have shown that most people breathe far too much per minute, that they're engaging in anywhere from 15 to 20 or even 30 shallow breaths per minute. So they are vastly overbreathing relative to how they should be breathing. Now, of course, if you breathe more deeply, so you take a vigorous inhale [INHALES] and then you expel that air, well, then to get six liters of air into your system per minute, you're probably only going to need somewhere between four and six breaths in order to get that six liters per minute. Now, the total time that it takes to do that inhale and exhale isn't that much longer than a shallow breath, provided you're not deliberately breathing quickly during those shallow breaths. So then you say, well, how is it that normal healthy breathing that delivers the appropriate amount of carbon dioxide into the system and doesn't expel, doesn't exhale too much carbon dioxide-- how are we supposed to do that normal breathing? Are you supposed to breathe four times and then hold your breath until the minute passes? No. What you find is that the correct pattern of breathing is going to involve two things. First of all, nasal breathing, because of the resistance it provides through the nose that we talked about earlier, is going to deliver more oxygen into your system. You're going to be able to generate more air pressure to fill your lungs. That greater air pressure is going to take longer to exhale. So already we're increasing the amount of time that each breath is going to take. And also what you find is that people that are breathing in the proper healthy manner, that is, that are balancing oxygen and carbon dioxide in the proper ways, are also taking pauses between breaths. This is extremely important. Because even though we have a brain center, the pre-Botzinger complex, that can control or, I should say, does control inhale-exhale rhythmic breathing, those pauses between breaths are not always present and, in fact, often are not present from people's baseline breathing patterns. As a consequence, they overbreathe. And as I told you before, when people overbreathe, their brain becomes hyperexcitable at the level of the background noise. And yet they are less efficient at detecting and learning information. We'll get into the specific studies that really illustrate the learning aspect a bit later. But they are less efficient at detecting and learning information, at focusing, and so on as a consequence of this overbreathing and the hyperexcitability that it causes. Now, of course, that's also just emphasizing the effects of overbreathing and lack of carbon dioxide on the brain. There are hundreds, if not thousands of studies showing that when we don't have enough carbon dioxide in the tissues of our body, that's also problematic for all the tissues-- the liver, the lungs themselves, the stomach, et cetera-- that relate largely to shifts in pH because of the fact that carbon dioxide strongly regulates the acidity, alkalinity of the blood and the tissues that that blood supplies nutrients to, including carbon dioxide. So the basic takeaway here is you want to breathe in a healthy manner at rest. And the best way to do that is to spend some time-- and it doesn't take much, maybe a minute or so each day-- paying attention to how quickly you are breathing per minute when you are simply at rest, when you're making coffee in the morning, when you're sitting down to read, when you're on social media. Chronically holding your breath isn't good but neither is overbreathing. And, again, every study that has examined the typical patterns of breathing and patterns of breathing that show up as normal and abnormal has found that more often than not, during the nighttime, people are underbreathing. And in the daytime, they are overbreathing. They're hyperventilating.

01:09:44 Tool: Train Healthy Breathing, Carbon Dioxide Tolerance Test & Box Breathing

So next, I'd like to address what you can do about your normal patterns of breathing, that is, how you or anyone can adjust their normal patterns of breathing from an unhealthy to an unhealthy state. But the first thing we have to do, of course, is determine whether or not you're already breathing in an unhealthy or in a healthy way. And, again, when I say healthy or unhealthy, I mean, are you overbreathing? Are you underbreathing? Are you delivering the appropriate ratios of oxygen and carbon dioxide to the tissues of your brain and body? In order to do this, we're going to do a simple test. Again, please don't do this while driving or operating heavy machinery or near water of any kind. But assuming that you're not doing any of those things, I encourage you to sit down, certainly not lie down but just sit down. I suppose you also could do it standing. And we are going to do what's called the carbon dioxide tolerance test. The carbon dioxide tolerance test is a sort of back of the envelope measure of how well you are managing carbon dioxide, that is, how well you can control your breathing at both the mechanical and the chemical level. It's a very simple test. What you're going to do is for the next 10 seconds or so while I'm speaking, you're just going to breathe normally. Now, again and again throughout this episode, I'm going to encourage you to be a nasal breather whenever possible. But of course, there are instances in which you want to engage mouth breathing. But for the time being, as I continue to blab on for the next few seconds, just inhale through your nose, exhale through your nose. You don't have to deliberately slow your breathing or increase the cadence of your breathing. However, in that time, you're also going to want to find some sort of time measuring device, like could be your phone or it could be a stopwatch. What I'm going to ask you to do in a few minutes is I'm going to ask you to inhale through your nose as deeply as you possibly can. That is, you're going to fill your lungs as much as you can through your nose. And then start a timer and measure how long it takes for you to deliberately control that exhale until your lungs are empty. So this is going to be a controlled exhale through the nose after a big deep breath. But for the time being, keep breathing at a kind of calm, regular cadence. So you can find that time measuring device now, or you can come back to it later if you like. When I say inhale, you're going to inhale as deeply as you can through your nose, remembering that the diaphragm can really help you here to get a deep inhale by having your belly move out while you inhale. And then when I say start, you're going to measure the time that it takes to do a complete lungs empty exhale. In fact, I'll measure it for you. This will be one of the rare instances in this podcast where there's going to be a long period of silence as I measure something. So I've got a stopwatch here. So please prepare to do the big inhale and start inhaling now. So inhale as deeply as you can through your nose. Fill your lungs as much as you can. OK? Now start, meaning slowly control the exhale through your nose. You're trying to let that air out as slowly as possible. And I'm just going to call out every 10 or 15 seconds or so. And you want to note when your lungs are empty. I know you can hold your breath with your lungs empty. That is not an accurate measure. 15 seconds. It is important that when note your lungs are empty and that you're trying to control the exhale as much as possible so that you don't arrive at that lungs empty time too quickly. I'll explain what too quickly means. 30 seconds. OK, for those of you that have already reached lungs empty, please go back to breathing normally. For those of you that haven't, you can hang in here a little longer if you're still discarding that air. 45 seconds. And we're rounding toward a minute, not quite there. Some of you are probably still letting out that air. I want to point out none of this has to do with cardiovascular fitness level, at least not in any kind of direct way. And 60 seconds. And I realize there will be a small subset of you out there that are still expelling your air in a slow lungs-- slow exhale manner through the nose. OK, so what we just did is a back of the envelope carbon dioxide discard rate if you need to pause this and go back and try it again you just want to time how long it takes you to go from lungs full to lungs empty, again, with the full understanding I know that you can all sit there like beasts and hold your breath with your lungs empty. But please don't do that because that's not going has been informative for what I'm telling you now. What I'm going to tell you now is that if it took you 20 seconds or less to expel all your air, that is, you couldn't extend that exhale longer than 20 seconds, in a kind of back of the envelope way, we can say that have a relatively brief or low carbon dioxide tolerance. If it took you somewhere between 25 and 40, maybe 45 seconds to expel all your air, that is, you could control that exhale for about 45 seconds or 30 seconds, then you have a moderate level of carbon dioxide tolerance. And if, for instance, you were able to go 50 seconds or longer for that discard until you hit lungs empty, you have a fairly high degree of carbon dioxide tolerance. Now, here's the deal. If you had low carbon dioxide tolerance, that is, you're 20 seconds or less, you're going to write down the number three. If you had moderate levels of carbon dioxide tolerance, you're going to write down the number five. or you could even put five to six. And then if you are in that bracket of people that was able to discard your air over a period of 50 seconds or more, you're going to write down the number 8 to 10. OK? Now, what are these numbers? What are we talking about? And before we get into what to do with these numbers, I want to emphasize again, this does not have to do with fitness level per se. I know some world class triathletes that have very fast carbon dioxide blow-off times. That is, their discard rates are 20 seconds or less. I should also point out that if you're very stressed, that number is going to be very small. If you're very relaxed, like you just woke up after a long night of sleep and you feel great, that number is going to be extended. So this is a back of the envelope measure that you're going to use each time you decide to do the exercise I'm going to tell you about in a moment. And the exercise I'm going to tell you about in a moment can be done every day if you like. But what the most interesting studies, at least to me, indicate is that you could do the exercise I'll tell you about even just once or twice a week and greatly improve your efficiency of breathing and shift yourself away from overbreathing when at rest, even if you're not thinking about how you're breathing at rest. So what is this exercise? Well, you just got your number, either low, medium, or high bracket number for carbon dioxide discard rate. Remember, if you're in the low category, your number is three. If you're medium, it's five to six. And if you are in the long carbon dioxide discard rate, long duration carbon dioxide discard rate, that is, 8 to 10 is your number. Now you're going to do two minutes of what most people would call box breathing. What is box breathing? Box breathing are equal duration inhale, hold, exhale, hold, repeat. So inhale, hold, exhale, hold. Sounds very easy, right? How long do you inhale and then hold, exhale and then hold? Well, you now know. If you are in the low group of carbon dioxide discard rate, your inhale is going to be three seconds, your hold will be three seconds, your exhale will be three seconds, and then you repeat, three seconds. So each side of the box, if you will, is going to be three seconds long. If you were in the moderate carbon dioxide discard rate category, then you're going to inhale for five to six seconds, hold for five to six, exhale for five to six, hold for five to six, repeat for about two minutes. You could do three minutes if you want. But I think it's important to have protocols that are feasible for most people. And that's going to mean doing things for about two to five minutes when it comes to these breath rehabilitation exercises for restoring normal breathing. And then, of course, if you are in the long category of carbon dioxide discard rate, you should be able to do an 8 to 10 second inhale, 8 to 10 second hold, 8 to 10 second exhale, 8 to 10 second hold, and repeat. So you could do that exercise now if you like, or you could do it at some point offline. You can pause this podcast if you want and go try it. That's an exercise that you can do for about two to three minutes once or twice per week. What's happening when you do that exercise? Well, first of all, you are greatly increasing your neuromechanical control over the diaphragm. This is very important. Most people are not aware of this phrenic nerve pathway in the diaphragm. And you are greatly increasing your mechanical control over this pathway through the process we call neuroplasticity. When you deliberately focus on a aspect of your nervous system control and particular nervous system control over musculature that normally is subconscious and you're not paying attention to and when you actively take control of that, it requires that your brain adjust and rewire the relationship between the different components of that circuit. And the wonderful thing is that has been shown to lead to changes in your resting pattern of breathing. Now, why did we go through the whole business of doing the carbon dioxide tolerance test? Well, for people who don't tolerate carbon dioxide very well, they don't have very good phrenic, that is, neuromechanical control of the diaphragm, for whatever reason-- again, it doesn't mean you're not fit. It just means you don't have or you have not yet developed neuromechanical control of the diaphragm. It would be near impossible for you to do box breathing for two or three minutes with eight seconds in, eight seconds hold, eight seconds exhale, eight second hold. So that's why we do a test to see what you're capable of doing. You don't want the box breathing to be too strained where you're [GRUNTS],, where you're really challenged to get around the whole box. You want it to be relatively easy because, remember, you're trying to translate this pattern to your normal pattern of breathing, that is, your pattern of breathing when you're not consciously thinking about breathing. And what are we really translating when we do this box breathing type exercise? What you're translating is the ability to pause between breaths and yet take full mechanically-driven breaths that involve the phrenic nerve and diaphragm. So, again, you're encouraging, especially if you use nasal breathing when you do the box breathing-- you're encouraging phrenic control over the diaphragm. And you're getting that six liters of air per minute or so using fewer and fewer breaths over time. So this is a, again, zero cost-- although it does cost a little bit of time-- zero cost approach to adjusting your normal pattern of breathing at rest, which has a huge number of positive outcomes in terms of your ability to stay relatively calm, to not get the hyperexcitability of the brain. It has actually been shown in various studies-- and we'll talk about one in particular later-- to greatly improve not just levels of calm and reduce bouts of stress but also improve nighttime sleep. There are huge number of benefits that can come from doing this box breathing exercise. But you got to get the duration of the size of the box right, and that's why you do the carbon dioxide tolerance test. One thing that many people notice after doing the carbon dioxide tolerance test even just once and then doing this box breathing exercise once or twice a week is that after two or three weeks, the box breathing itself becomes very easy. And in that case, I recommend taking the carbon dioxide tolerance test over again. And almost always what you'll find is that you have been able to extend your carbon dioxide discard rate, and therefore, you now fall into a different category, not just the lower medium but the long carbon dioxide discard rate category, and you are able to extend the duration of those inhale, hold, exhale, holds during the box breathing. And, of course, the ultimate benefit of all this is that it translates to deeper and yet less frequent breathing when at rest and when not consciously paying attention to how you're breathing during the daytime. Again, if at all possible, do all of this breathing through the nose. For those of you that have a severely occluded nose, the recommendation always is to breathe through your nose more. But I do realize that for some people, it's really uncomfortable to breathe through the nose because they have such an occluded nasal pathway. And for you folks, doing some of this breathing through the mouth can probably suffice. But if at all possible, do the breathing through the nose. And please also let me know how your progress evolves over time with the carbon dioxide discard rate and the box breathing. And of course, the positive shifts that occur in normal unconscious daytime breathing translate to all the opposite things that we talked about when you are overbreathing during the daytime. So what I just described in terms of the carbon dioxide tolerance test and the exercise using box breathing

01:22:39 Tool: Breathwork & Stress Reduction; Cyclic Sighing

to restore normal patterns of breathing and not overbreathe and therefore not eliminate too much carbon dioxide is exactly the two tests that were incorporated into a study that my laboratory did in collaboration with our associate chair of psychiatry at Stanford School of Medicine, Dr. David Spiegel, who's also been a guest on this podcast previously. And that study explored box breathing. But it also explored other forms of breathing and actually compared those forms of deliberate breathing to meditation as a means to explore what are going to be the minimal effective doses and most effective ways to chronically reduce stress around the clock and improve mood and improve sleep. So the study I'm referring to was just published recently. It's entitled "Brief Structured Respiration Practices Enhance Mood and Reduce Physiological Arousal." We will also provide a link to this paper in the show note captions. What this study really focused on was a simple question, which is, what is the shortest and most effective practice that people can use in order to reduce their levels of stress not just during that breathwork practice or meditation practice but around the clock, 24 hours a day, including improvements in sleep? And we were excited to do this study because many studies had explored how meditation or, in some cases, fewer studies have explored how breathwork can impact different brain states or bodily states. But very few studies had explored how those breathwork or meditation practices influenced body-brain states around the clock when people were not performing the particular meditation or breathwork practice. The reason we were able to do this study was really fortunate. The folks over at WHOOP were generous enough to donate a bunch of WHOOP straps, which allowed us to measure heart rate variability, a number of other different physiological parameters. We also got subjective reports about people's mood and feelings of well-being. We got data about their sleep pinged to us from remote locations. So these people, rather than being brought to the laboratory and being in a very artificial circumstance, the laboratory, as much as we like to think our laboratory is realistic-- we have virtual reality and things like that-- there's nothing as realistic as the real world. And so we were able to have more than a hundred subjects out in the real world living their real lives pinging back to us data all the time, 24 hours a day so that we could measure how their different interventions that we asked them to do, breathwork practices or meditation practices, were impacting physiological parameters. And they were also informing us regularly about their subjective mood, et cetera. We got a lot of data, as you can imagine. And the basic takeaway from the study was twofold. First of all, we discovered that deliberate breathwork practices done for about five minutes per day across the course of about a month led to greater reductions in stress than did a five minute a day meditation practice. Now, that is not to say that meditation is not useful. In fact, there are dozens, if not hundreds, of papers, including one particular, I should say, particularly beautiful study from Wendy Suzuki's lab at New York University showing that a daily 10 to 13 minute mindfulness meditation practice can greatly improve focus, memory, and a number of other things related to cognition and learning. However, the research on meditation has shown us that meditation, at least short meditations, mainly lead to improvements in focus and memory, not so much reductions in stress, although they do lead to reductions in stress. What we found was that any number of different breathwork practices-- and we explored three-- done for five minutes a day outperformed meditation in terms of the ability of breathwork to reduce stress around the clock compared to meditation. The three types of breathwork that we explored also showed different effects. I should mention the three types of breathwork that we compared were box breathing of the sort that you just learned about. We compare that to something called cyclic sighing, which involves two inhales through the nose to get maximally inflated lungs followed by a long exhale. I'll return to that in a moment. That was repeated for five minutes at a time for each session. And a third breathwork practice, which was cyclic hyperventilation, which, as the name suggests, involves people inhaling deeply through the nose, then exhaling passively through the mouth, and then repeating inhale through the nose, exhale through the mouth, repeating that for 25 cycles, one cycle being an inhale and an exhale. So that equals one cycle. Repeating that for 25 cycles, then exhaling all their air and holding their breath with lungs empty for about 15 to 30 seconds, and then repeating inhale, exhale, cyclic hyperventilation for the duration of five minutes. So people were divided into these different groups, either mindfulness meditation where they sat, they were not told to control their breathing in any specific way. They closed their eyes. They focused their attention on a region just behind their forehead. One group did that. The other group did cyclic sighing. Another group did box breathing. Another group did cyclic hyperventilation. As any sort of clinical trial like this ought to, we then swapped people into different groups. So they served as their own control. So we could evaluate any between and within individual variability. Again, there are a lot of data in this paper. But the takeaway was that for the sake of stress reduction around the clock and for the sake of improving sleep and mood, the most effective practice of the four practices that we examined was the cyclic sighing. Again, cyclic sighing is performed the following way. You inhale through the nose as deeply as you can. Then you do a second inhale immediately afterwards to try and maximally inflate the lungs. In fact, that's what happens. We know that during that second inhale, even if it's just a very sharp, short inhale, the extra physical vigor that's required to generate that second inhale causes those alveoli of the lungs, which may have collapsed-- and, indeed, in between breaths and often even just through the course of the day and especially if we get stressed, those alveoli of the lungs start to collapse. And because they're damp on the inside-- they have a little bit of fluid. They're like a balloon with a little bit of fluid in the middle. It takes a little bit of physical force to pop those open. Now, you're not literally exploding them pop. But you're reinflating them with air. And then you perform the long exhale through the mouth until lungs are empty. So it looks exactly like this. [INHALES DEEPLY] [INHALES SHARPLY] [EXHALES] Now, we know that one single physiological sigh of the sort that I just described performed at any time of day under any conditions, whether or not you're about to walk on stage to give a talk or you're in a meeting and you're feeling stressed, or you're in a conversation that's very stressful, or you can feel stress mounting because you're in traffic or any number of psychological or physical stressors that may be approaching you or you feel are oppressing you, doing one physiological sigh of the sort that I just described is the fastest physiologically verified way that we are aware of to reduce your levels of stress and to reintroduce calm, that is, to shift your autonomic nervous system from a state of heightened levels of autonomic arousal. That is, sympathetic nervous system as, it's called, is at a higher activation level than the so-called parasympathetic nervous system. Again, sympathetic nervous system having nothing to do with sympathy, has everything to do with so-called fight or flight, although it controls other things, too, including positive arousal. And the parasympathetic nervous system, often referred to as the rest and digest system, although it does other things, too, is associated with calming. Those two things are always in kind of push-pull with one another, like a seesaw or push-pull, however you want to think about it. One physiological sigh, meaning that big, deep inhale, short second inhale also through the nose, and then long exhale to completely lungs empty, is known to restore the level of balance in the sympathetic-parasympathetic neural circuitry and is the fastest way to reintroduce calm. That's one physiological sigh. In this study, what we asked was that people perform that repeatedly, so-called cyclic sighing, for the duration of five minutes. And the people who did that cyclic sighing for five minutes a day, regardless of the time of day that they did it, experienced the greatest reductions in stress not just during the practice but around the 24-hour cycle. And it translated, again, to all sorts of positive subjective changes-- improvements in sleep, lower resting heart rate at all times of day. So this is important. Again, this study was not just exploring what happens during meditation or breathwork, cyclic sighing, et cetera. It was exploring how the changes that occur during that practice translate to changes in breathing and heart rate, mood, et cetera, throughout the 24-hour cycle. So the takeaway here is twofold. First of all, if you are somebody who wants to improve your mood and reduce your overall levels of stress and you only have five minutes a day to invest in that, hopefully you're doing all the other things like trying to get proper sleep and exercise, social connection, nutrition, et cetera, sunlight in the morning, of course. Can't leave that out. But if you were going to devote five minutes a day to a stress reduction practice that is now supported by data to translate to reductions in stress around the clock, the data say that you would want to invest that in cyclic sighing, that is, double inhale through the nose, extended exhale through the mouth until your lungs are empty, then repeat for five minutes a day. You, of course, if you like, could do meditation. It still had positive effects, meaning it reduced stress, although not as much as cyclic sighing. You could do box breathing if you want for the purpose of reducing stress. All the practices we explored did reduce stress. But cyclic sighing performed for five minutes a day had the most robust and pervasive effect in reducing stress, improving mood, and improving sleep. That's the first message of the study. The second takeaway is that one physiological sigh-- that's right just one physiological sigh, where you inhale deeply through the nose another inhale through the nose to maximally inflate the alveoli of the lungs, and then you exhale to completely lungs empty and then go back to normal breathing, is the fastest way to introduce a level of calm and to reduce your overall levels of stress in real time. And this is very important. I think that out there these days, we hear a lot about stress reduction techniques. And most all of the stress reduction techniques that have been explored, everything from massage to meditation to breathwork to a hot shower to a foot rub, will calm you down. The question is, do they calm you down just during that practice? Great if it does. But does it also translate to reduced levels of stress at other times in the 24-hour cycle and other positive effects as well? So one physiological sigh is a very efficient way to adjust that ratio of sympathetic to parasympathetic activation and immediately bring about calm. So it's excellent for real-time control of stress. The other thing about physiological sighs is that it's not a hack. It's not the application of a breathing practice to something that it wasn't intended for. In fact, physiological sighs were not discovered by me at all. They were discovered by physiologists

01:33:56 Tool: Physiological Sighing & Exercise Side Cramp

in the 1930s, who found that when people underbreathe, they have a buildup of carbon dioxide in their system. And even though carbon dioxide is essential for life, you don't want too much of it in your system. And that people, whether or not they were asleep or awake, would engage a physiological sigh spontaneously, subconsciously. They would do this double inhale through the nose and extended exhale through the mouth. And that did not just eliminate excessive carbon dioxide from the system. It also rebalanced the oxygen-carbon dioxide ratio in the proper ways. In fact, it's observed in animals. You might see this in animals that are tired. When animals or humans get tired, they tend to start underbreathing a little bit, and that can often disrupt the balance of carbon dioxide and oxygen. And right before a dog will go down for a nap, for instance, you'll notice that it'll do this double inhale, exhale. people when they are sleeping, if they hold their breath for a period of time, which, frankly, all of us do periodically throughout sleep, they will engage a spontaneous physiological sigh. During the daytime, we are often holding our breath, especially nowadays-- and there's a study on this that we'll talk about a little bit later-- where when people text message or they're emailing, although nowadays people are mainly on social media and text messaging, they often are holding their breath. They will follow a breath hold by a physiological sigh because during that breath hold, they're building up the level of carbon dioxide in their system. Now, mind you, I spent close to a half an hour telling you that most people are overbreathing at rest, and that's also true. But people often will shift from overbreathing to underbreathing, which is a terrible pattern. So physiological sighs done either as a one-off, one physiological sigh to clamp stress or reduce stress in real time, or repeatedly over five minutes as a practice that you do each day is going to be not just the most effective way to approach reducing stress around the clock and in real time but also the one that's highly compatible with the way that the neural circuits that control breathing were designed. The physiological sigh has some other very useful applications. One of the more, I would say, useful ones, at least to those of you that exercise, is going to be the use of physiological sigh in order to remove the so-called side stitch. So if you've ever been running or swimming or exercising and you felt a cramp on your right side, chances are, despite what your high school PE coach told you, that raising your arms above your head or drinking less water before you exercise is not going to get rid of that cramp. And here's why. It's not a cramp at all. If you recall the cervical 3, 4, and 5 nerves that give rise to the phrenic nerve and go down and innervate your diaphragm, well, as I mentioned before, a certain number of those nerve fibers actually course into the diaphragm and go up underneath. And if you recall earlier, I also said that the diaphragm sits right on top of the liver. In other words, you actually have a sensory innervation of the diaphragm, the deep diaphragm, and the liver. And there's something called referenced pain, which is what people generally experience when they have that side stitch on their right-hand side. So if you're ever exercising and you feel a cramp on your right-hand side, it's possible that it's a genuine cramp. But more likely is the fact that that phrenic nerve sensory innervation is now being carried up to your brain and you are detecting some local or referenced pain in the liver and in the diaphragm. Now, that doesn't necessarily mean you're doing anything wrong, although you might not be breathing properly for running at that moment, and that's what gave rise to it. It could be some spasming of the phrenic nerve or some inefficient breathing during running. We had an entire series on fitness with Dr. Andy Galpin. One of those episodes included a lot of information on breathing. It was the episode on endurance, although breathing was a topic that was thread through multiple episodes in that series. You can find that series at HubermanLab.com. Talks a lot about how to breathe during running, how to breathe during weightlifting, et cetera. But the point for now is that if ever you're experiencing that right-side side stitch, I encourage you to perform the physiological sigh. And the good news is you can perform it while still running or while still swimming, although I suppose with swimming, you might have to make some adjustments because, of course, you don't want to inhale water, or while cycling or any type of activity. If you perform that physiological sigh generally two or three times, what will occur is that because of changes in the firing of the phrenic nerve, and in particular because of changes in the sensory feedback from the sensory component of the phrenic nerve back to the brain, you will experience an alleviation of the pain from that right-side side stitch. In other words, you can get rid of side cramps doing physiological sighs during activities, in particular during running activities. Now, I should also mention that if you're experiencing a side stitch on the left-side, chances are that has to do with excessive air or fluid in your stomach. And there are reasons for that that also have to do with the way that the phrenic nerve is-- it's bilateral and branches to both sides and is catching sensory input on the left side from some of the local organs and sensory innervation of those organs. But if you have right-side side stitch, the physiological sigh done two or three times while still running ought to relieve that side stitch. Now, as long as we're talking about breathing and the phrenic nerve and the relationship between the phrenic nerve and your liver and your stomach

01:39:16 Breathing & Heart Rate Variability

and some of the other organs in that neighborhood, we should talk about the relationship between breathing and heart rate. This is an incredibly important topic, so much so that I perhaps should have brought it up at the beginning of the episode. But nonetheless, you now know what your diaphragm does. When you inhale, your diaphragm moves down. That's right. When you contract your diaphragm, it moves down. It creates space for your lungs to inhale. And when you exhale, your diaphragm moves up. Well, when you inhale and your diaphragm moves down, what happens is there's more space created in the thoracic cavity and particularly if you're also breathing deeply and you're using those intercostal muscles to expand your ribs. As a consequence, the heart actually gets a little bit bigger. It's a temporary enlargement in the heart. But it's a real enlargement. And as a consequence, whatever blood is in the heart is now in a larger volume because the heart got bigger. And as a consequence, that blood is moving more slowly through that larger volume for a short period of time. But nonetheless, it's moving more slowly. Your nervous system detects that and sends a neural signal to the heart to speed the heart rate up. In other words, inhales increase heart rate. The opposite is true when you exhale. When you exhale, your diaphragm moves up. Your rib cage tends to move inward a bit. And you compact the heart. You reduce the volume of the heart overall. When you reduce the volume of the heart overall, blood flow through the heart accelerates because it's a smaller volume. So a given unit of blood is going to move more quickly through that small volume. Your nervous system detects that and sends a signal to slow the heart down. So just as inhales speed the heart up, exhales slow your heart rate down. Now, of course, even though you can double up on inhales or even triple up on inhales, sooner or later, if you inhale, you're going to have to exhale. And the converse is also true, of course. So what does this mean in terms of controlling your heart rate? Well, let's say you are going in for a blood draw, or you're going out on stage and you're stressed. Well, I would encourage you to do a physiological sigh, maybe two physiological sighs to bring your level of calm up and your level of stress down. Nonetheless, if you have any reason why you want to quickly reduce your heart rate or accelerate your heart rate for sake of physical work output or to calm yourself down additionally, not just use the physiological sigh, well, then you can take advantage of this relationship between inhales and exhales controlling heart rate. If you want to increase your heart rate, you can simply inhale longer and more vigorously relative to your exhales. And if you want to decrease your heart rate, well, then you're going to make your exhales longer and/or more vigorous than your inhales. In fact, this process, which is called respiratory sinus arrhythmia, is the basis of what we call heart rate variability. Heart rate variability involves the vagus nerve, the 10th cranial nerve, which is a parasympathetic nerve that is associated with a calming aspect of the autonomic nervous system, slowing your heart rate down by extending your exhales. And it really forms the basis of most all breathing practices. If you look at any breathing practices, whether or not it's Wim Hof breathing, Tummo breathing, Kundalini breathing, Pranayama breathing, physiological sighing, cyclic sighing, and on and on and on, if you were to measure the ratio of inhales to exhales and the vigor of inhales to exhales, what you would find is that each one would create a net increase or a net decrease in heart rate that could be very accurately predicted by whether or not that breathing practice emphasized inhales, emphasized exhales, or had those two features, inhale and exhale, be of equal duration and intensity. In fact, if you wanted to equilibrate your heart rate, what you would do is you would do box breathing because inhale, hold, exhale, hold is, by definition, creating equal duration inhales and exhales of essentially equivalent vigor. When you do a physiological sigh, you're doing two big inhales, which is going the speed your heart rate up just a little bit, but then a long extended exhale. The exhale in the end is much longer than the two inhales even when combined. And so you get a net decrease in heart rate, the calming effect. And then practices such as Tummo breathing or Wim Hof breathing or cyclic hyperventilation, [HYPERVENTILATES] deep inhales and exhales, the inhales are more vigorous compared to the more passive exhales-- are going to lead to increases in heart rate. So the relationship between breathing and heart rate is an absolutely lockstep one where your heart rate follows your breathing. Your heart rate and your breathing are in an intimate discussion with one another, but where always and forever your inhales increase your heart rate, your exhales decrease it. Now, this feature, which physicians call respiratory sinus arrhythmia, or we sometimes hear about more often nowadays as heart rate variability, is something that people in sport have known about for a very long time. It's why, for instance, that marksmen will exhale just prior to taking a shot. That's particularly true for people that compete in the biathlon, where they cross country ski. So their heart rate is up, up, up, up, up. Then they'll get to the point where they actually have to shoot a target, and they'll exhale, and then they'll shoot the target. This is also why, for instance, if you want to bring your heart rate down very quickly between rounds of martial arts, there are a number of different ways to do that. But an extended exhale of any kind or, frankly, any breathing practice that emphasizes exhales is going to bring your heart rate down. This has been incorporated in a number of different contexts, including sport, military. It's also now being incorporated in a clinical context for people who feel a panic attack coming on. I'm very gratified to learn that the physiological sigh is now being explored as a tool to prevent panic attacks and anxiety attacks. This is prior to the panic attack, people bringing their heart rate down, again, through those extended exhales. So learning to extend your exhale is really a terrific skill to master, and it's a very easy skill to master, frankly. Why do I say a skill? Well, remember what I said earlier, which is that humans inhale actively and most typically will passively exhale, just let the air [EXHALES] drop out of them at whatever rate, depending on how much air they inhaled. Actively exhaling, that is, actively relaxing the diaphragm and actively relaxing those intercostal muscles of the chest, those ones that are, I should say, between the ribs, is a skill that you can very quickly acquire and will allow you to use that relationship between the phrenic nerve, the diaphragm, and the size of the heart, the heart volume, and all that stuff to really take control of heart rate quickly. So that if you feel like your heart is racing too much-- and, frankly, a lot of people have a lot of what's called interoceptive awareness, especially anxious people. They can really sense what's going on in their body, other people less so. Like, oh my god, my heart's beating. It's ready to jump out of my chest, and I don't like that. I don't like that. [EXHALES] Big, long exhale. It doesn't matter if you do it through the nose or the mouth. Big, long exhale is going to allow you to slow your heart rate down. Let's talk about hiccups. Everybody experiences hiccups from time to time. I think most people would agree that one hiccup is sort of funny.

01:46:21 Tool: How to Stop Hiccups

Two hiccups in a row is really funny. And three hiccups in a row is where it starts to be concerning, in part because hiccups can be kind of painful. You can experience pain in your gut or your lower abdomen and sometimes in your chest as well. And it feels kind of intrusive. It gets in the way of having conversation or just sitting there and relaxing. Fortunately, there's a simple way to get rid of hiccups. And you can arrive at that simple technique if you understand a little bit about what gives rise to hiccups. The reason we get hiccups at all is because we experience a spasm of the phrenic nerve. The phrenic nerve, as you recall, is a nerve that emanates from the cervical region, to be specific C3, 4, and 5. Those spinal nerves go down, of course, behind the heart and innervate the diaphragm, which is the muscle that when it contracts, it moves down and allows the lungs to fill. And then when you relax the diaphragm, then the diaphragm moves up, and the lungs shrink or they expel air, so-called exhalation. Now, the phrenic nerve also has that sensory branch. So it's not just involved in controlling the diaphragm at the motor level. It's also sensing things deep within the diaphragm and in the liver as well because the liver sits right below the diaphragm. So a hiccup has that painful sensation from time to time because there's a rapid sensory feedback or a signal, rather, of a sharp sensation of contraction within the diaphragm. And that's relayed back to the brain. And you consciously perceive that as a little bit of pain. And then, of course, the hiccup is [HICCUPS] the hiccup, which is the spasming of the phrenic nerve that you experience more or less in your throat. But all this really is happening along the phrenic nerve and toward the diaphragm. What this all means is that if you can stop the phrenic nerve from spasming, you can stop hiccups. There are a lot of approaches that people have tried to take to eliminate spasming of the phrenic nerve. You'll hear that breathing into a bag, which is one way to reingest or reinhale carbon dioxide that otherwise would be expelled out into the environment, can help. That's a very indirect method. It rarely works, frankly, because it really has to do more with adjusting your breathing to try and adjust the activity of the phrenic nerve. It's a really roundabout way of trying to alleviate hiccups. Some people will experience relief from drinking from a glass of water from the opposite side of the glass. So you have to tilt over at the waist. It's a kind of messy approach. Again, it doesn't tend to work a lot of the time. For some people, it works every time. But for most people, it doesn't work at all. However, there is a technique that can reliably eliminate hiccups. And it's a technique that takes advantage of hypercontracting the phrenic nerve over a short period of time so that it then subsequently relaxes or alleviates the spasming of the phrenic nerve. And that simple method is to inhale three times in a row. This is a very unusual pattern of breathing. But what it involves is taking a big, deep inhale through your nose. Then before you exhale any air, take a second inhale through the nose, however brief that inhale might be, and then a third even micro or millisecond long inhale through your nose to get that third inhale. And then hold your breath for about 15 to 20 seconds, and then slowly exhale. So even though I'm not experiencing any hiccups right now. I will demonstrate the method for eliminating hiccups so that you're all clear on how to do it. OK, here I go. [INHALES DEEPLY] [INHALES] [INHALES] [EXHALES] OK, so it's three inhales all through the nose. And it is true that that second and third inhale takes some physical effort to really get additional air into the lungs without exhaling first. It feels like-- the only way I can describe it really is as a sharp second and third inhale because you really have to engage the musculature of those intercostal muscles and the diaphragm in order to do it. And then that long exhale can be through the nose or the mouth. But I find it particularly relaxing or even pleasant to do it through the nose. This method of three inhales through the nose followed by a long exhale through the nose or mouth will eliminate hiccups right away because what it does is it hyperexcites the phrenic nerve three times in a row, a very unnatural pattern for the phrenic nerve to fire. And then it undergoes a hyperpolarization, as we call it, in which the phrenic nerve actually stands a much lower probability of getting activated again for some period of time afterwards. So it is important that you try and return to normal cadence of breathing after doing this three inhales followed by a long exhale. If you need to perform it a second time in order to eliminate hiccups because they're simply not going away, that's fine. You can do that. But as far as we know, this is the most efficient and science-supported way to eliminate hiccups. Now, up until now I've been talking about breathing techniques, and I've mainly focused on breathing techniques that emphasize the exhale,

01:51:17 Tool: Stress Management & Cyclic Hyperventilation, “Wim Hof Method”

whether or not it's the carbon dioxide tolerance test, whether or not it's cyclic sighing or the physiological sigh that you use in real time to reduce stress. One thing that we haven't talked about so much is cyclic hyperventilation. Cyclic hyperventilation, as you recall, is a bout of 25 or so breaths inhaling deeply through the nose and then passively exhaling or sometimes actively exhaling, typically through the mouth. So it might look like this. [HYPERVENTILATES] That's a very active inhale through the nose and exhale through the mouth. It can also be done active inhale through the nose, passive exhale through the mouth, like so. [HYPERVENTILATING] In any event, that pattern of breathing repeated for 10 to 25 breaths greatly increases levels of autonomic arousal. In fact, it's known to deploy adrenaline from the adrenals. And in our study, we had people then expel all their air, so breathe out, hold their breath for 15 to 30 seconds, and then repeat for a period of five minutes. That did lead to some very interesting and positive physiological changes in terms of stress mitigation, although not as significant as was observed with cyclic sighing, as I talked about earlier. Now, there is a lot of interest in cyclic hyperventilation for sake of, for instance, extending breath holds. This has become popular in part because of the so-called Wim Hof method, which is a method that combines breathing, cyclic hyperventilation, followed by lungs full or lungs empty breath holds, depending on which variant of the Wim Hof method one is using. Separately-- and I really want to emphasize separately-- the Wim Hof method also involves deliberate cold exposure, which, as all of you know, I'm a big fan of and we've done episodes of this podcast on. And we have toolkits on deliberate cold exposure for increasing dopamine levels, epinephrine levels, immune system function, et cetera. Wim Hof method also incorporates that. And it has a mindfulness component. I do want to caution people that any time you're doing cyclic hyperventilation, you want to be very cautious about not doing it in or near water because it does greatly increase the risk of shallow water blackout. And that's because when you do cyclic hyperventilation, you are expelling, you're exhaling more carbon dioxide than usual. And what I haven't told you yet is that the trigger to breathe is actually an increase in carbon dioxide. What I mean by that is you have a small set of neurons in your brainstem that can detect when carbon dioxide levels in your bloodstream reach a certain level. And when they reach that level, they trigger the gasp reflex and/or the hunger for breathing. In other words, we don't breathe because we crave oxygen, although we do need oxygen, of course, in order to survive and for our brain to function and our bodily organs to function. But our brain is wired such that it has a threat sensor, which is carbon dioxide levels are getting too high, and that's what triggers the motor reflex to breathe and to, in some cases, gasp for air, depending on how starved for air we are. So if you do cyclic hyperventilation, whether or not it's Wim Hof method or whether or not it's Tummo method-- again, these things are similar. They're not exactly the same. There are other breathing methods that incorporate cyclic hyperventilation. What you're doing is you're getting rid of a lot of carbon dioxide, and therefore, you're removing the impulse or lowering the impulse to breathe so that when you enter that breath hold phase after the hyperventilation, it's a much longer period of time before you feel the anxiety and the hunger and the impulse to breathe. That's one of the real benefits of any technique that incorporates cyclic hyperventilation, is that rather than reduce your stress level in real time, it actually does the opposite. It increases your stress level. It increases your levels of autonomic arousal. But you're doing it deliberately. And then during those breath holds, what's happening is you have a lot of adrenaline circulating in your system because of the way that hyperventilation triggers the release of adrenaline from your adrenal glands. It also triggers the release of epinephrine, which is the same as adrenaline, from a little brain area called locus coeruleus, which makes you feel more alert. And then during those breath holds and in the subsequent rounds of cyclic hyperventilation, people experience what it is to have a lot of adrenaline in their system. But they are controlling the release of that adrenaline, which is far and away different than when life events are triggering that adrenaline. So what it really is is a form of self-induced stress inoculation. And I do think there are benefits to practicing cyclic hyperventilation because it does allow you to learn how to self-deploy adrenaline and epinephrine from locus coeruleus and from the adrenals. Or I got that backwards-- adrenaline from your adrenals and epinephrine from locus coeruleus. And it allows you to explore what it is to maintain calm state of mind and body when you have a lot of adrenaline in your system, which certain studies are starting to show can allow people to be able to lean into the stressful aspects of life. And let's be honest, life is stressful in any event. And we're all going to experience stress at some point or another. And when we do, we want to make sure that we're not overtaken by the release of adrenaline from the adrenals, that sudden surge of epinephrine from locus coeruleus. So doing cyclic hyperventilation maybe one or two times per week-- again, 25 breaths, active inhale, passive or active exhale. Do expect to feel tingly because of that reduction in carbon dioxide from exhaling so much. Do expect to feel a little bit agitated. Be very careful doing this if you're somebody who has anxiety attacks or somebody who has panic attacks or disorders of any kind. But if you don't and you want to explore this, you'll notice you start to feel really ramped up. And then during the breath holds, which, again, can be done by exhaling and stopping for some period of time, 15, maybe even 60 seconds, is a time in which you can explore how to remain mentally calm. Some people even choose to do math problems or think of things in a kind of structured way while they have a lot of these hormone neurotransmitters circulating at high levels in their system, in other words, as a way to learn to manage your mind and body under conditions of stress. Now, if you are somebody who's using deliberate cold exposure, either cold showers or ice baths or cold immersion,

01:57:11 Deliberate Cold Exposure & Breathing

I often get asked how best to breathe during those different types of activities. Really, there's no best way to breathe. Although if you wanted to turn those activities into their own form of stress inoculation, again, please don't use cyclic hyperventilation. That's dangerous. I don't recommend it whatsoever. But you can try to actively slow your breathing, that is, to make sure that you're engaging in rhythmic breathing. Now, up until now I've said that rhythmic breathing is the default. Pre-Botzinger nucleus controlling rhythmic breathing is the default and that doubling up on inhales and exhales is something that happens when you deliberately take over the action of pre-Botzinger complex. Now, that's true 99% of the time. However, there are certain conditions, such as conditions of heightened state of emotional arousal-- if you think about somebody who's been crying, oftentimes they'll do the double inhale, exhale [INHALES SHAKILY] or triple inhales. Or if somebody is very, very afraid, it's all inhales. So it does sometimes happen spontaneously. Actually, when we get into very cold water, there's a very robust decrease in the activation of the prefrontal cortex, which is the area of brain real estate right behind the forehead that controls structured thinking, your ability to reason and make sense of what's going on. If you get into really cold water, you should not expect that brain region to work or at least not work very well at all for the first 20 or 30 seconds that you're in the cold water. From the time you get into cold water, because here we're talking about deliberate cold exposure, I encourage you to try and control your breathing and make it rhythmic, that is, inhales follow exhales follow inhales follow exhales, even if they have to be fast inhale exhale, inhale, exhale. Why? Because the default when we get into a stressful circumstance, emotionally or physically stressful circumstance, is that rhythmic breathing stops and that parafacial nucleus takes over and it's [INHALES RAPIDLY],, and it's that kind of panicky mode. And by simply controlling our breath, again, even if it's fast from inhale to exhale and making sure that we're alternating inhales and exhales rhythmically-- and what you'll find is that you'll be able to navigate that what would otherwise be a very stressful circumstance and make it less stressful or maybe even pleasant. And that skill definitely translates to other aspects of life in which you're hit square in the face with something stressful. You'll notice your breathing and your pattern of breathing switching to multiple inhales or breath holding, essentially departing from rhythmic breathing. And by quickly returning to rhythmic breathing and maybe even trying to slow the breathing and extend those exhales, you'll find that you can very quickly calm down. Next, I'd like to discuss what I find to be an absolutely fascinating topic. It's also one that's highly useful in the world, which

01:59:54 Tool: Inhales & Learning; Exhales & Movement

is how your specific patterns of breathing relate to your ability to learn and to remember information, how it can modulate fear, and a number of other aspects of how your brain functions. This is a literature that's been reviewed recently in a lot of exquisite detail in a beautiful review by Jack Feldman, who I mentioned earlier, one of the pioneers of the neuroscience of breathing. The title of the review is "Breathing Rhythm and Pattern and Their Influence on Emotion." Again we'll, provide a link to this review in the show note captions. This review includes discussion of several studies, one in particular that I'll get into in a bit of detail, that describes the following. Right now, I just want you to breathe regularly, meaning rhythmically. You can inhale and exhale through your mouth or through your nose. I'd prefer that you do it through your nose because nasal breathing, unless you need to breathe through your mouth because of hard exercise or eating or talking, is always going to be the better way to go. Nasal breathing improves the aesthetic of your face. That's been shown. We'll talk about that just briefly in a few minutes. Nasal breathing improves the amount of oxygen you can bring into your system, et cetera, et cetera. OK, so just breathe. Inhale, exhale, inhale, exhale. And know that during your exhales, your pupil, that is, the pupil of your eye, is getting bigger. And as you exhale, it's getting smaller. In addition, when you inhale, your reaction time to anything that happens around you-- a car swerving in front of you, something that you might detect in the periphery of your vision or hear off in the distance-- increases significantly compared to when you're exhaling. In addition, when you are inhaling, your ability to remember things, especially things that take a bit of effort to remember, and your ability to learn new information is significantly greater than it is when you're exhaling. Now, as you hear all that, you're probably thinking, OK, how do I just inhale? Well, of course, that's not going to be the best approach. You need to exhale as well for all the reasons you now are well aware of. But what these findings really illustrate-- and I should mention these findings are all carried out in humans. So these relate to some stuff in animal studies. But what I just described has been shown in human studies consistently. When we inhale and, in particular, when we inhale through our nose, our brain is not functioning in the same way as when we exhale. Now, that doesn't mean that our brain is functioning in a deficient way when we exhale. It just doesn't function as well as it relates to memory retrieval, memory formation, and some other aspects of cognition. Now, you might be asking, why in the world would this be? Well, I wasn't consulted at the design phase, and anyone that tells you that they were you should back away from quickly. But one reasonable explanation for why our brain functions better, at least in the context of what I just talked about, when we inhale is because the olfactory system is actually the most ancient sensory system of all the sensory systems we have. So before vision, before audition, before touch, before all of that, the olfactory system is the most ancient system. And the olfactory system, of course, is designed to detect chemicals in the environment. And so if you imagine an early organism that perhaps we evolved from or perhaps we didn't but nonetheless that we share some features of, at least in terms of olfactory function, in order to get that chemical information into the brain, you need to inhale. You need to bring that information in. Now, for aquatic animals, they could take it in through water. But for animals that are terrestrial that live on land, they would have to get it through the air. So inhalation, we know, activates certain regions of the so-called piriformis cortex. These are areas of the neocortex that are more ancient, as well as increasing the activity of brain areas such as the hippocampus, which is a brain area involved in learning and memory. In fact, one of the studies that illustrates this most beautifully is a study that was published in The Journal of Neuroscience in 2016. By the way, Journal of Neuroscience is a very fine journal. And the title of this paper is "Nasal Respiration Entrains Human Limbic Oscillations and Modulates Cognitive Function." This is a paper that followed up on an earlier paper that showed that when people breathe in through their nose, their recognition and their discrimination of different odors was far greater than when they breathe in through their mouth. Now, that result was interesting, but it was also sort of a duh because you smell things with your nose, not your mouth. You taste things with your mouth, and you speak with your mouth, and there are bunch of other things you can do with your mouth. But nonetheless, that study pointed to the idea that the brain is different during nasal inhalations versus nasal exhalations versus mouth inhalations versus exhalations. What it basically showed is that the brain ramps up its levels of activity, and that signal to noise that we talked about earlier, if you recall, that ability for the brain to detect things in the environment, is increased during inhalations. But because that earlier study focused on smell, on olfaction, there was a bit of a confound there. It was hard to separate out the variables. So this paper, the one I just mentioned, "Nasal Respiration Entrains Human and Limbic Oscillations and Modulates Cognitive Function," did not look at detection of odors. Rather, it looked at things like reaction time or fear. And basically, what it found is that reaction time is greatly reduced when people are inhaling. So they had people look at fearful stimuli. They looked at their reaction time to fearful stimuli, in other words, their ability to detect certain kinds of stimuli. And they were given a lot of different kinds of stimuli. So they had to be able to discriminate between one sort of--oops, excuse me. By the way, folks, for those listening, I just bumped the microphone, getting rather animated here. What the subjects had to do was detect one type of stimulus versus another stimulus that they were being exposed to. And what they found is if people were inhaling as that fear-inducing stimulus was presented, their reaction time to notice it was much, much faster. And they related that to patterns of brain activity, and they were able to do that because they were actually recording from the brain directly from beneath the skull. And they were able to do that because they had some patients that had intracranial electrodes embedded in their brain for sake of trying to detect epileptic seizures. So there's a lot to this study and a lot that we could discuss. But the basic takeaway is that when people are inhaling, that is, when they're drawing air in through their nose in particular, their ability to detect what's going on in the world around them is greatly enhanced and not just for fear but also for surprise of all sorts. So when people are inhaling, their ability to detect novel stimuli, things that are unexpected or that are unusual in their environment, is significantly increased. Again, we'll put a link to this study as well. I find it to be one of the more interesting studies in this realm, although there are now many additional studies that support this statement that I made earlier, which is that during inhalation, also called inspiration, there are a number of very fast physiological changes, such as changes in pupil diameter, changes in the activity of the hippocampus, this memory encoding and retrieval area of the brain, and other areas of the brain. So what's the tool takeaway from this? If you are sitting down to read or research or study or you really want to learn some information-- maybe you're listening to a podcast or some other sorts of information that you want to retain-- it actually makes sense to increase the duration or the intensity of your inhales as you do that. The more that you're inhaling relative to exhaling in terms of duration, the more that your brain is in this focused mode and this mode of being able to access and retrieve information better. Now, there's one caveat to this that I think is important because I know a number of people listen to this podcast for sake of gleaning tools not just for cognitive enhancement but for physical enhancement. It turns out that when you are inhaling air, you're actually less able or, I should say, less efficient at generating voluntary movements. Now, that might come as a surprise. Up until now, we've basically been talking about inhalation is great, almost to the point where you wonder like, is the exhalation good for anything? You don't want to overbreathe and kick out too much carbon dioxide. Well, of course exhalation is great for things. In fact, if you're somebody that's played baseball or softball, what are you told? That you should exhale on the swing to generate the maximum amount of power. If you're somebody who has done martial arts of any kind, was traditional Western boxing, as you strike, that's where people typically do the hiya, laying the sort of classic karate type thing. That's more of a movie thing. I don't know whether or not people actually use the hiya. But in boxing, oftentimes people will do [EXHALES SHARPLY].. They'll do a rapid exhalation, a forceful exhalation, keeping in mind, again, that inhales typically are active. They engage the diaphragmatic muscle. They engage those intercostal muscles. Whereas exhales tend to be passive unless we take active control of the exhale. And, indeed, our ability to generate fast, directed, so-called volitional, voluntary movements is greatly enhanced if we do them during the exhale, not the inhale. Now, with all of that said, I haven't yet really talked about mouth versus nasal breathing.

02:09:15 Mouth vs. Nasal Breathing, Aesthetics

And it really can be a fairly short discussion because what abundant data now show and has been beautifully described in the book called Jaws, A Hidden Epidemic-- this is a book that was written by Paul Ehrlich and Sandra Kahn, my colleagues at Stanford School of Medicine. It has an introduction and a foreword from Jared Diamond and from the great Robert Sapolsky. So some real heavy hitters on this book. What that book really describes is that whenever possible, meaning unless you're speaking or eating or you're exercising or other activities require some change in your pattern of breathing, we should really all be striving to breathe through our nose, not through our mouth. And that relates to the increased resistance to breathing through the nose we talked about earlier. Again, I'll say it a third time, that increased resistance through the nose allows you to inflate your lungs more, not less. The other thing that breathing through your nose allows you to do is it both warms and moisturizes the air that you bring into your lungs, which is more favorable for lung health than breathing through the mouth. Hard breathing through the mouth or simply mouth breathing at all is actually quite damaging or can be, I should say, quite damaging to some of the respiratory functions of your lungs. That, of course, does not mean that you shouldn't breathe hard through your mouth when you're running or sprinting or exercising hard. But you don't want mouth breathing to be the chronic default pattern that you follow. Nasal breathing (Nasal Strips) is the best pattern of breathing to follow as a default state. Another aspect of nasal breathing that's really beneficial is that the gas nitric oxide is actually created in the nasal passages. It's a gas that can cause relaxation of the smooth muscles that relate to the vasculature not just of your nose but of your brain and for all the tissues of your body. This is why nasal breathing and not mouth breathing is great for when you want to relieve congestion. So a lot of these things seem counterintuitive. Your nose is stuffed. So that mainly makes people breathe through their mouth. But it turns out that breathing through your nose will allow some dilation of the vasculature, more blood flow, dilation of the nasal passages, and delivery of nitric oxide to all the tissues of your body. And that dilation of the small capillaries that innervate essentially every organ of your body allow the delivery of more nutrients and the removal of carbon dioxide and other waste products from those tissues more readily than if you're not getting enough-- excuse me-- nitric oxide into your system. So a lot of reasons to be a nasal breather. If you want to check out that book Jaws, A Hidden Epidemic, it's a terrific read. And it also shows some absolutely striking pictures, twin studies and so forth, and some before and afters of people and the aesthetic changes that they experienced when they shifted from being a mouth breather to a nose breather. These are striking examples that have been observed over and over again. When people mouth breath, there's an elongation of the jaw, drooping of the eyelids, and the entire jaw structure really changes in ways that are not aesthetically favorable. Fortunately, when people switch to becoming nasal breathers-- and, of course, that takes some encouragement either by mouth taping or doing their cardiovascular exercise with mouth closed or by doing the sorts of exercises that we talked about earlier. When they switch to becoming nasal breathers by default, the aesthetic changes that occur are very dramatic and very favorable, including elevation of the eyebrows, not in an artificial sense or in a kind of outrageous way, but elevation of the cheekbones, sharpening of the jaw, and, most notably, improvements of the teeth and the entire jaw structure. In fact, one simple test of whether or not you can be an efficient nasal breather and whether or not you've been nasal breathing efficiently or most of the time in the past or whether or not you've been relying more on mouth breathing that was described in the book Jaws is you should be able to close your mouth and breathe only through your nose. Again, this is at rest, not during exercise necessarily, though you might do it during exercise. But close your mouth, put your tongue, on the roof of your mouth, and it should fit behind your teeth. And you should be able to nose breathe in that position. Now, many people won't be able to do that. But fortunately, as I mentioned earlier, if you nasal breathe, that is, you deliberately nasal breathe when at rest for some period of time, you will experience an increased ability to nasal breathe (Nasal Strips). And you should also experience some addition of space within the palate of your mouth to allow your tongue to sit more completely on the roof of your mouth. This is especially true for children that perform this technique. Again, I refer you to the book Jaws, A Hidden Epidemic. It's an absolutely spectacular book. You can also just look online "before and after Jaws, Hidden Epidemic" and look at some of the changes in facial structure that occur when people move from mouth to nasal breathing, and it's really quite striking. So during today's episode, per always, we covered a lot of information. First, we talked about the mechanical aspects of breathing-- the lungs, the diaphragm, the trachea, and so forth. We also talked about the chemical aspects of breathing, that really breathing is a way that we bring oxygen to our cells and that we get the correct levels or, I should say, we maintain the correct levels of carbon dioxide in our system, neither too much nor too little, in order to allow oxygen to do its magic and to allow carbon dioxide to do its magic. Because as you learned during today's episode, carbon dioxide is not just a waste byproduct. It has very critical physiological functions. You need to have enough of it around. And therefore, you don't want to overbreathe, especially at rest. We talked about a tool to measure how well you manage carbon dioxide, the so-called carbon dioxide tolerance test, and various exercises that you can use simply by breathing to decrease your stress in real time, decrease your stress chronically around the clock. Obviously, that's a good thing-- improve sleep, improve mood. How to increase breath hold times and why you might want to do that. Also how to eliminate hiccups. We talked about how to breathe in order to eliminate the side stitch or side cramp that you might experience during exercise and how to breathe in order to improve learning and memory, reaction time, and various other aspects of cognitive and physical function. I do realize it's a lot of information. But as always, I try and give you information that is clear, hopefully interesting as well, and actionable toward a number of different endpoints. So if you're somebody that's just now starting to think about the application of breathwork, I would encourage you to please, yes, do that carbon dioxide tolerance test. That will give you some window into how well or how poorly you're managing breathing. And then here's the great news. The great news is that breathwork, that is, deliberate respiration practices, are very effective at creating change very quickly. In some cases, such as the use of the physiological sigh or cyclic hyperventilation, those changes can be experienced the first time and every time because, again, these are not hacks. These are aspects of your breathing apparati, including the mechanical stuff and the neural stuff and the gas exchange stuff, all of which you were born with and that are available to you at any moment. So all you really have to do is explore them and deploy them as you feel necessary.