

Using Salt to Optimize Mental & Physical Performance | Huberman Lab Podcast #63

I discuss the role of salt (sodium) in the nervous system and the key role that it plays in mental performance, physical performance and health. I explain how the brain senses salt levels in our body and how that relates to our feelings of thirst. I cover the physiology of the renal system and the hormones that control sodium and water balance in our body. I also explore how salt interacts with stress and our immune systems and its crucial role in neuron function. Additionally, I examine research findings suggesting that some individuals might benefit from increased intake of sodium and other electrolytes (magnesium and potassium) to enhance mental performance, lessen anxiety, and offset dizziness. Yet, other people may need less sodium. I discuss how you can determine your optimal sodium intake and why sodium intake levels need to be uniquely tailored to an individual's lifestyle. Finally, I explain how salt creates 'hidden' sugars in many processed foods and the problems that can create. Throughout the episode, I explain peer-reviewed findings outlining salt's essential role in overall health and describe general recommendations and tools anyone can use to find their optimal salt balance and thereby enhance their brain and body's performance.

#HubermanLab #Hydration #Salt

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"The preference for sugar over sweetener depends on a gut sensor cell":

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Book Links

"The Salt Fix: Why the Experts Got It All Wrong--and How Eating More Might Save Your Life": <https://amzn.to/3CD1KHi>

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- Welcome to the Huberman Lab Podcast, where we discuss science and science-based tools for everyday life. [authoritative music] I'm Andrew Huberman, and I'm a professor of neurobiology and ophthalmology at Stanford School of Medicine. Today, we are going to discuss salt, also referred to as sodium. Now, most of us think of salt as something that we put on and in our food, maybe something to avoid. Maybe some of you are actually trying to get more salt. Some of you are trying to get less salt. We all seem to associate salt with things like blood pressure, et cetera. Today, we are going to go down a different set of avenues related to salt. We will certainly cover how salt regulates blood pressure. We are also going to talk about how the brain regulates our appetite for salt or our aversion for salt. We are also going to talk about how our sensing of salty tastes

actually mediates how much sugar we crave and whether or not we ingest more or less sugar than we actually need, so what you're going to learn today is that the so-called salt system, meaning the cells and connections in our brain and body that mediate salt craving and avoidance, are regulating many, many aspects of our health and our ability to perform in various contexts, things like athletic performance, things like cognitive performance. We're also going to talk about aging and dementia and avoiding aging and dementia and what role salt and salt avoidance might play in that. We're going to touch on some themes that, for some of you, might seem controversial, and indeed, if they are controversial, I'll be sure to highlight them as such. I'm going to cover a lot of new data that point to the possibility, I want to emphasize the possibility, that for some people, more salt might help them in terms of health, cognitive, and bodily functioning, and for other people, less salt is going to be better. I'm going to talk about what the various parameters are. I'm going to give you some guidelines that, in concert with your physician, who you should absolutely talk to before adding or changing anything to your diet or supplementation regime, can help you arrive at a salt intake that's going to optimize your mental, physical health, and performance, so we're going to cover neurobiology. We're going to cover hormone biology. We're going to talk about liver function. We're going to talk about kidney function and, of course, brain function. I'm excited to share this information with you today.

00:02:18 The Brain-Body Contract

I'm certain you're going to come away with a lot of information and actionable items. I'm pleased to announce that I'm hosting two live events this May. The first live event will take place in Seattle, Washington on May 17th. The second live event will take place in Portland, Oregon on May 18th. Presale tickets for these two events are now available at hubermanlab.com/tour. I should mention that while I do hope to visit other cities in the near future to do more live events, right now, these are the only two live events I have scheduled, at least for the six months, so once again, if you go to hubermanlab.com/tour, you can access the presale tickets. I hope to see you at these live events,

00:02:57 Neuropod Cells, Artificial Sweeteners & 'Hidden' Cravings

and as always, thank you for your interest in science. Before we dive into the topic of today's episode, I want to highlight a really exciting new study. This is a study from Diego Bohorquez' lab at Duke University. The Bohorquez Lab studies interactions between the gut and the brain and has made some incredible discoveries of the so-called neuropod cells. Neuropod cells are neurons, nerve cells, that reside in our gut and that detect things like fatty acids, amino acids, and some neuropod cells sense sugar. Previous work from this laboratory has shown that when we ingest sugar, these neuropod cells respond to that sugar and send electrical signals up a little wire that we call an axon through the vagus nerve, for those of you that want to know, and into the brain, and through subsequent stations of neural processing, evoke the release of dopamine. Dopamine is a molecule known to promote craving and motivation and indeed action, and what these neuropod cells that send sugar are thought to do is to promote seeking and consumption, eating of more sugary foods. Now, the incredible thing is that it's all subconscious. This is a taste system in the gut that is not available to your conscious awareness. Now, of course, when you ingest sweet foods, you taste them on your mouth too, and so part of the reason that you crave sweet foods, perhaps, is because they taste good to you, and the other reason is that these neuropod cells are driving a chemical craving below your conscious detection, so they're really two systems. Your gut is sensing, at a subconscious level, what's in it and sending signals to your brain that work in concert, in parallel with the signals coming from your mouth and your experience of the taste of the food. Now, that alone is incredible, and it's been the subject of many important landmark papers over the last decade or so. You can imagine how this system would be very important for things like hidden sugars when nowadays, in a lot of processed foods, they're putting hidden sugars. They're putting a lot of things that cause your gut to send signals to your brain that make you crave more of those foods, so for those of you that really love sugar, just understand it's not just about how that sugar tastes. The new study from the Bohorquez Lab deserves attention, I believe. This is a paper published just recently, February 25th this year, 2022, in "Nature Neuroscience," an excellent journal, and the title of the paper is "The Preference for Sugar over Sweetener Depends on a Gut Sensor Cell." The Bohorquez Lab has now discovered a neuropod cell, meaning a category of neurons, that can distinguish between sweet things in the gut that contain calories, for instance, sugar, and things in the gut that are sweet but do not contain calories: artificial sweeteners like aspartame, sucralose, and so forth. There are also, of course, nonartificial, noncaloric sweeteners

like stevia, monk fruit, et cetera. They did not explore the full gallery of artificial sweeteners. What they did find, however, ought to pertain to all forms of sweet, noncaloric substances. What they discovered was that there is a signature pattern of signals sent from the gut to the brain when we ingest artificial or noncaloric sweeteners. This is important because what it says is that at a subconscious level, the gut can distinguish between sweet things that contain calories and sweet things that do not. Now, what the downstream consequences of this sensing is or what they are isn't yet clear. Now, I believe everyone should be aware of these kinds of studies for a couple of reasons. First of all, it's important to understand that what you crave, meaning the foods you crave and the drinks you crave, is, in part, due to your conscious experience of the taste of those things, but also due to biochemical and neural events that start in the body and impinge on your brain and cause you to seek out certain things even though you might not know why you're seeking out more sugar. You find that you're craving a lot of sugar, or you're craving a lot of foods with artificial sweeteners, and you don't necessarily know why. Now, artificial sweeteners themselves are a somewhat controversial topic. I want to highlight that. Some months back, I described a study from Yale University about how one can condition the insulin system. Insulin is involved in mobilizing of blood sugar and so forth in the body, as many of you know, and I described some studies that were done from Yale University School of Medicine looking at how artificial sweeteners can actually evoke an insulin response under certain conditions. Now, a couple of key things. I got a little bit of pushback after covering those studies, and I encourage pushback all the time. Pushback is one of those things that forces all of us to drill deeper into a topic. I want to be clear. First of all, I am not one to demonize artificial sweeteners. There is evidence, in animal models, in animal models, that artificial sweeteners can disrupt the gut microbiome, but those were fairly high doses of artificial sweeteners, and it's unclear if the same thing pertains to humans, still unclear, I should say, has not been investigated thoroughly. Some people don't like the taste of artificial sweeteners. Some people do. Some people find that they really help them avoid excessive caloric intake. Some people believe, and yet I should emphasize there still isn't evidence that they can adjust the insulin response in all people. I just want to repeat that three times so that people are clear on that fact. What these new data emphasize, however, is that we need to understand how artificial sweeteners are consumed at the level of the gut, or I should say registered at the level of the gut and how that changes brain function because one thing that I'm familiar with and that many people report is that

when they first taste artificial sweeteners, they taste sort of not right to them. They don't like the taste, but over time, they actually start to crave that taste. I've experienced this. I used to drink a lot of diet sodas when I was in graduate school, so this would be aspartame, and I found that I would, I actually needed them. Now, maybe it was the caffeine. Maybe I just liked the sweet taste or the carbonation. We actually have a drive for carbonation, which is a topic of a future episode, but when I finally quit them, for reasons that were independent of any fear of artificial sweeteners, I found that I didn't like the taste. Nowadays, I only occasionally drink a diet soda. I usually do that if I'm on a plane and there's nothing else available to me, so I don't demonize them. I might drink one every once in a while. No big deal. I also want to be clear I consume stevia on a number of different supplements and foods that I consume. Stevia, of course, is a plant-based noncaloric sweetener, so I, myself, consume artificial sweeteners. Many people hate them. Many people like them and find them useful for their nutrition, and in fact, to keep their caloric intake in a range that's right for them, and many people, like myself, are curious about them and somewhat wary of them and yet continue to consume them in small amounts. I think most people probably fall into that category. I should also mention that many food manufacturers put artificial sweeteners, such as sucralose, et cetera, into foods, and it's always been unclear as to why they might want to do that, and yet we know that the sweet taste consumption, even if it doesn't contain calories, can drive more craving of sweet food, so there may be a logic or a strategy to why they do that. Again, a topic for exploration on today's podcast and in future podcasts because where we're headed today is a discussion about how salt and salt sensing, both consciously and unconsciously, can adjust our craving for other things, like sugar and water and so on, so I want to highlight this beautiful work from the Bohorquez Lab. We'll put a link to the study. I want to open this as a chapter for further exploration. I like to think that the listeners of this podcast are looking for answers where we have answers, but are also, I would hope, excited about some of the new and emerging themes in what we call nutritional neurobiology, and indeed, the Bohorquez Lab really stands as one of the premier laboratories out there that's looking at how foods, as consumed in the gut,

00:10:57 AG1 (Athletic Greens), LMNT, InsideTracker

are modifying our nervous system, the foods we crave, and how we utilize those foods. Before where we begin, I'd like to emphasize that this podcast is separate from my

teaching and research roles at Stanford. It is, however, part of my desire and effort to bring zero cost to consumer information about science and science-related tools to the general public. In keeping with that theme, I'd like to thank the sponsors of today's podcast. Our first sponsor is Athletic Greens, now called AG1. I've been taking AG1 since 2012, so I'm delighted that they're sponsoring the podcast. The reason I started taking AG1 and the reason I still take AG1 once or twice a day is that I find it to be the best way to ensure I get all of my vitamins and minerals and the probiotics I need. I try and eat really well, but I'm not perfect about it, and with Athletic Greens, AG1, I cover any deficiencies I might have. The probiotics are particularly important to me because, as we've talked about on many previous episodes and we'll talk about more on today's episode, the gut microbiome is supported by probiotics, and the gut microbiome supports many biological functions important for immediate and long-term health, things like immune system function, things like the gut-brain axis and mood and appetite and so forth. With Athletic Greens, I make sure all of those bases are covered because of the probiotics. If you'd like to try Athletic Greens, you can go to athleticgreens.com/huberman to claim a special offer. They'll give you five free travel packs, which make it really easy to mix up Athletic Greens while you're on the road, and they'll give you a year's supply of vitamin D3+K2. Vitamin D3 is crucial for many aspects of our immediate and long-term health, and many people simply are not getting enough vitamin D3, or the amounts they're getting are not optimal. K2 is important for cardiovascular health and for calcium regulation, so again, if you go to athleticgreens.com/huberman, you can claim the special offer, the five free travel packs and a year's supply of vitamin D3+K2. Today's episode is also brought to us by LMNT. LMNT is an electrolyte drink that has everything you need and none of the things you don't. That means it has salt, magnesium, and potassium, the so-called electrolytes, which are critical for neuronal function and a lot of other biological functions. As I mentioned on the podcast before, I'm a fan of salt. I believe in ingesting appropriate amounts of salt, and by appropriate, I mean, depending on what your background blood pressure happens to be, what your activity levels are, how much you sweat, what your cognitive and physical demands are. Today, we're going to talk about how to determine what those needs are. I'm always trying to stay on top of my hydration, and as you'll also learn about today, salt and water intake and hydration are intimately related. With LMNT, I'm sure to get the potassium, the sodium, and the magnesium that I need, and I do that in a great-tasting drink, and as I mentioned before, it has no sugar. If you'd like to try

LMNT, you can go to drinklmnt.com, that's drinklmnt.com/huberman to claim a free LMNT sample pack. You only cover the cost of shipping. Otherwise, it's completely free. Again, that's drinklmnt.com/huberman to claim a free sample pack of LMNT. Today's episode is also brought to us by InsideTracker. InsideTracker is a personalized nutrition platform that analyzes data from your blood and DNA to help you better understand your body and help you reach your health goals. I am a big fan of getting regular blood work done, and I've been trying to do it as much as I can afford for years. The reason is that many of the factors that impact our immediate and long-term health can only be discovered from a quality blood test. With most blood tests and DNA tests, however, you get information back, but not a lot of information about what to do with those numbers, so if something's in high or low range, you might get one or two generic recommendations, things that you could easily look up online, but you're not going to get a lot of specific recommendations. With InsideTracker, they give you a lot of specific recommendations as to lifestyle factors, nutrition factors, supplementation factors, things you may want to add to your life or things you may want to delete from your life in order to bring the numbers into the ranges that are best for your immediate and long-term health. There's simply no replacement for these kinds of data, and your data are the most important data to you, and quality blood tests and DNA tests are the way to access them. If you'd like to try InsideTracker, go to insidetracker.com/huberman

00:15:06 Salt Regulation

to get 20% off any of InsideTracker's plans. That's insidetracker.com/huberman to get 20% off. Okay, let's talk about salt. Salt has many, many important functions in the brain and body. For instance, it regulates fluid balance, how much fluid you desire and how much fluid you excrete. It also regulates your desire for salt itself, meaning your salt appetite. You have a homeostatically driven salt appetite. I'll talk about the mechanisms today, make them all very clear. What that means is that you crave salty things, beverages and foods, when your salt stores are low, and you tend to avoid salty beverages and foods when your salt stores are high, although that's not always the case. There are circumstances where you'll continue to crave salt even though you don't need salt or indeed even if you need to eliminate salt from your system. Salt also regulates your appetite for other nutrients, things like sugar, things like carbohydrates, and today, we'll explore all of that. Technically, salt is a mineral, and I should mention

that when I say salt, I am indeed referring to sodium, in most cases, although I will be clear to distinguish salt from sodium, meaning table salt from sodium. Most people don't realize this, but one gram of table salt contains about 388 milligrams of sodium, so technically, we should be talking about sodium today and not salt. I will use them interchangeably unless I'm referring to some specific recommendations or ideas about trying to define your ideal salt, aka sodium intake, okay? So this is important. I think, right off the bat, a lot of people get themselves into a place of confusion and potentially even to a place of trouble by thinking that table salt in grams always equates to sodium in grams, and that's simply not the case. Today, we're going to explore the neural mechanisms by which we regulate our salt appetite and the way that the brain and body interact in the context of salt-seeking, salt avoidance, how to determine when we need more salt, when we need less salt.

00:17:13 How the Brain Senses Salt

We'll talk about kidney function. We'll get into all of it, and we're going to do it very systematically, so let's start in the brain. We all harbor small sets of neurons. We call these sets of neurons nuclei, meaning little clusters of neurons, that sense the levels of salt in our brain and body. There are couple brain regions that do this, and these brain regions are very, very special, special because they lack biological fences around them that other brain areas have, and those fences, or I should say that fence, goes by a particular name, and that name is the blood-brain barrier, or BBB. Most substances that are circulating around in your body do not have access to the brain, in particular, large molecules can't just pass into the brain. The brain is a privileged organ in this sense. There are couple other organs that are privileged and that have very strict barriers, very particular fences, if you will, and those other organs include things like the ovaries and testes, and that makes sense for the following reason: First of all, the brain, at least most of the brain, cannot regenerate after injury. You just simply can't replace brain cells after injury. I know people get really excited about neurogenesis, the birth of new neurons, and indeed, neurogenesis has been demonstrated in animal models, and to some extent it exists in humans in a few places, for instance, the olfactory bulb, where neurons are responsible for detecting odorants in the environment, for smell, that is, and in a little subregion of the hippocampus, a memory area, there's probably some neurogenesis, but the bulk of really good data out there point to the fact that in humans there's not much

turnover of neurons. What that means is that the neurons you're born with are the ones that you're going to be using most, if not all, of your life. In fact, you're born with many more neurons than you'll have later, and there's a process of naturally occurring cell death called apoptosis, that occurs during development, so you actually are born with many more neurons than you have later in life, and that's the reflection of a normal, healthy process of nerve cell elimination, so the estimates vary, but anywhere from 1/3 to maybe even 1/2 or even 2/3 of neurons, depending on the brain area, are just going to die across development. That might sound terrible, but that's actually one of the ways in which you go from being kind of like a little potato bug flopping around helplessly in your crib to being an organism that can walk and talk and articulate and calculate math or do whatever it is that you do for a living, so the brain has a set of elements, these nerve cells and other cells, and it needs to use those for the entire lifespan, so having a BBB, a blood-brain barrier around the brain, is absolutely critical. The ovaries and testes have a barrier for, we assume, the reason that they contain the genetic material by which we can pass on our genes to our offspring, progeny, meaning make children, and those children will have our genes, or at least half of them, the other half from the partner, of course. If the cells within the ovaries and testes are mutated, well, then, you can get mutations in offspring, so that's very costly in the evolutionary sense, so it makes sense that you would have a barrier from the blood so if you ingest what's called a mutagen, if you ingest something that can mutate the genes of cells, you can imagine why there would be a premium on not allowing those mutagens to get into the brain, the ovaries, or the testes, okay? So the brain has this BBB, this blood-brain barrier around it, which makes it very, very hard for substances to pass into the brain unless those substances are very small or those substances and molecules are critically required for brain function. However, there are a couple of regions in the brain that have a fence around them, but that fence is weaker, okay? It's sort of like going from a really big wall thick electronic 24-hour surveillance fence where nothing can pass through except only the exclusive cargo that's allowed to go through to having a little cyclone fence with a couple holes in it, or it's a kind of a picket fence that's falling over, and substances can move freely in from the blood circulating in the body into the brain, and it turns out that the areas of the brain that monitor salt balance and other features of what's happening in the body at the level of what we call osmolarity, at the concentration of salt, reside in these little sets of neurons that sit just on the other side of these weak fences, and the most important and famous of these, for sake of today's conversation, is one called OVLT.

OVLT stands for the organum vasculosum of the lateral terminalis. It is what's called a circumventricular organ. Why circumventricular? Well, not to bog you down with neuroanatomy, but your brain is a big squishy mass of neurons and other cell types, but it has to be nourished, and through the middle of that brain, there is a tube, there's a hollow, that creates spaces, and those spaces are called ventricles. The ventricles are spaces in which cerebrospinal fluid circulates, and it nourishes the brain. It does a number of other things as well. The circumventricular organs are areas of the brain that are near that circulating fluid, and that circulating fluid has access to the bloodstream, and the bloodstream has access to it, and this structure that I'm referring to, OVLT, organum vasculosum of the lateral terminalis, has neurons that can sense the contents of the blood and, to some extent, the cerebrospinal fluid. There are couple other brain areas that can do this as well. They go also by the name of circumventricular organs, and I'll talk about the names of some of those other areas, but for today, and I think for sake of most of the discussion, understand that the OVLT is special. Why? Because it doesn't have this thick barrier fence, which sounds like a bad thing, and yet it's a terrific border detector. The neurons in that region are able to pay attention to what's passing through in the bloodstream and can detect, for instance, if the levels of sodium in the bloodstream are too low, if the level of blood pressure in the body is too low or too high, and then, the OVLT can send signals to other brain areas, and then, those other brain areas can do things like release hormones that can go and act on tissues in what we call the periphery, in the body, and, for instance, have the kidneys secrete more urine to get rid of salt that's excessive salt in the body or have the kidneys hold onto urine, to hold onto whatever water or fluid that one might need, so before I go any deeper into this pathway, just understand that the OVLT has a very limited barrier. It can detect things in the bloodstream, and this incredible area of the brain, almost single-handedly, sets off the cascades of things that allow you to regulate your salt balance, which turns out to be absolutely critical, not just for your ability to think and for your neurons to work, but indeed, for all of life. If the OVLT doesn't function correctly,

00:24:15 Salt & Thirst

you're effectively dead or dead soon, so this is a very important brain region, so let's talk about the function of the OVLT and flesh out some of the other aspects of its circuitry, of its communication with other brain areas and with the body in the context of something

that we are all familiar with, which is thirst. Have you ever wondered just why you get thirsty? Well, it's because neurons in your OVLT are detecting changes in your bloodstream, which detect global changes within your body, and in response to that, your OVLT sets off certain events within your brain and body that make you either want to drink more fluid or to stop drinking fluid. There are two main kinds of thirst. The first one is called osmotic thirst, and the second is called hypovolemic thirst. Osmotic thirst has to do with the concentration of salt in your bloodstream, so let's say you ingest something very, very salty. Let's say you ingest a big bag of, I confess I don't eat these very often, but I really like those kettle potato chips, and they're pretty salty. I've never actually measured how much sodium is in them. I'm sure the information is there. Every once in a while, I'm particularly interested in doing so, I'll just down a bag of those things, and I really like them, and they're very salty, but they almost always make me feel thirsty, and the reason is that by eating those, I've ingested a lot of sodium. Again, not a frequent occurrence for me, but happens every now and again, and I don't have too much shame about that because I think I have a pretty healthy relationship to food and I enjoy them, and I understand that it will drive salt levels up in my bloodstream, and that will cause me to be thirsty, but why? Why? Because neurons in the OVLT come in two main varieties. One variety senses the osmolarity of the blood that's getting across that weak little fence that we talked about before, and when the osmolarity, meaning the salt concentration of the blood, is high, it activates these specific neurons in the OVLT, and by activates, I mean it causes them to send electrical potentials, literally, send electrical signals to other brain areas, and those other brain areas inspire a number of different downstream events, so what are those other brain areas? Well, the OVLT signals to an area called the supraoptic nucleus. The name and why it's called the supraoptic nucleus is not necessarily important. It also signals to the so-called paraventricular nucleus, another nucleus that sits near the ventricles and can monitor the qualities, the chemical qualities of the cerebrospinal fluid as well as, probably, the bloodstream as well, and the consequence of that communication is that a particular hormone is eventually released from the posterior pituitary. Now, the pituitary is a gland that sits near the roof of your mouth. It releases all sorts of things like growth hormone and luteinizing hormone. Luteinizing hormone will stimulate things like estrogen and testosterone production and release from the ovaries and testes and so on. The pituitary has a bunch of different compartments and functions, but what's really cool about the pituitary is that certain regions of the pituitary actually contain the axons, the wires of neurons, and the neurons

reside in the brain, and so the supraoptic nucleus gets a signal from the OVLT. The signal is purely in the form of electrical activity. Remember, neurons aren't talking in one another about what's happening out there. They're not saying, "Psst! "Hey, there's too much salt in the bloodstream. "Let's do something about it." All they receive are so-called action potential, waves of electricity. The neurons in the supraoptic nucleus then release their own electrical signals within the pituitary, and some of those neurons and nearby neurons are capable of releasing hormones as well as electrical signals, so from the pituitary, there's a hormonal signal that's released called vasopressin. Vasopressin also goes by the name antidiuretic hormone, and antidiuretic hormone has the capacity to either restrict the amount of urine that we secrete, or, when that system is turned off, to increase the amount of urine that we secrete, so there's a complicated set of cascades that's evoked by having high salt concentration in the blood. There's also a complicated set of cascades that are evoked by having low concentrations of sodium in the blood, but the pathway is nonetheless the same. It's OVLT is detecting those osmolarity changes, communicating to the supraoptic nucleus. Supraoptic nucleus is either causing the release of or is releasing vasopressin, antidiuretic hormone, or that system is shut off so that the antidiuretic hormone is not secreted, which would allow urine to flow more freely, right? Antidiuretic means anti release of urine, and by shutting that off, you are going to cause the release of urine. You're sort of allowing a system to flow, so to speak. The second category of thirst is hypovolemic thirst.

00:29:27 Blood Pressure & Thirst

Hypovolemic thirst occurs when there's a drop in blood pressure, okay? So the OVLT, as I mentioned before, can sense osmolarity based on the fact that it has these neurons that can detect how much salt is in the bloodstream, but the OVLT also harbors neurons that are of the baroreceptor, mechanoreceptor category. Now, more on baroreceptors and mechanoreceptors later, but baroreceptors are essentially a receptor, meaning a protein that's in a cell that responds to changes in blood pressure, so there are a number of things that can cause decreases in blood pressure. Some of those include, for instance, if you lose a lot of blood, right? If you're bleeding quite a lot, or in some cases, if you vomit quite a lot, or if you have extensive diarrhea or any combination of those, and there are other things that can reduce blood volume, and we will talk about some of those later, but in the classic case of hypovolemic thirst, one is simply losing blood, and

therefore, blood pressure goes down, so very simple to imagine in your mind. You have these pipes, which are the arteries, veins, and capillaries, and when you lose some blood volume, the pressure in those arteries, veins, and capillaries goes down. OVLT has neurons that can sense that reduction in blood pressure because of the presence of baroreceptors in OVLT. There are other elements that also play into the response to what we call hypovolemic thirst. For instance, the kidney will secrete something called renin. Renin will activate something called angiotensin II from the lungs, of all things, amazing, and angiotensin II itself can act on OVLT, organum vasculosum of the lateral terminalis, which, in turn, will create thirst, okay? So in both cases, right? The osmolarity sensing system, meaning osmotic thirst, and in hypovolemic thirst, where blood pressure has dropped, the end result is a desire to drink more, and that desire to drink more comes through a variety of pathways that are both direct and indirect, include vasopressin and don't include vasopressin, but I think, for just sake of general example, and even for those of you that don't have any biology background or physiology background, just understand that there are two main types of thirst. Both types of thirst, osmotic thirst and hypovolemic thirst, are not just about seeking water, but they also are about seeking salt. In very general terms, salt, aka sodium, can help retain water. Now, that doesn't mean that salt always retains water. If you have excessive amounts of salt, will you retain excessive amounts of water? Well, sort of. As we'll soon learn, it's all contextual, but for most cases, we can say that by having salt in our system, our brain and our body can function normally provided the levels of salt are adequate and not too high or too low, and thirst, while we often think of it as just a way to bring fluid into our body, is designed as a kind of an interoceptive perception. What I mean by that, interoception, as many of know now from listening to this podcast, is a paying of attention or a recognition, rather, a conscious recognition of the events going on within our body, so when we are thirsty, it's a certain form of interoception. We go, "Oh, I need something or I crave something." You may not know exactly what you need, but when you are thirsty, you're not just seeking water; you're also seeking to balance your osmolarity, which means you may be seeking salty fluids or foods, in some cases. You'll try and accomplish this by eating, or it may be that you're trying to avoid, or you will be inspired to avoid salty fluids and foods, but if you want to understand sodium and its roles in the body, you have to understand thirst, and if you want to understand thirst, you have to understand how fluid balance is regulated in the body. That's not surprising at all, but sodium and water work together in order to generate what we call thirst.

00:33:47 Kidneys & Urine Regulation

Sodium water work together in order to either retain water or inspire us to let go of water, to urinate, so before we can dive into the specifics around salt and how to use salt for performance and various recommendations and things to avoid, we need to drill a little bit deeper into this fluid balance mechanism in the body, and for that reason, we have to pay at least a little bit of attention to the kidney. The kidney is an incredible organ, and one of the reasons the kidney is so amazing is that it's responsible for both retaining, holding onto, or allowing the release of various substances from the body, substances like glucose or amino acids, urea, uric acid, salt, potassium, magnesium. It's basically a filter, but it's a very, very intelligent filter. I mean, intelligent meaning it doesn't have its own mind, but the way it works is really beautiful. Basically, blood enters the kidney and it goes through a series of tubes which are arranged into loops. If you want to look more into this, there's the beautiful Loop of Henle and other aspects of the kidney design that allow certain substances to be retained and other substances to be released, depending on how concentrated those substances are in the blood. The kidney responds to a number of hormonal signals, including vasopressin, in order to, for instance, antidiuretic hormone, in order to hold onto more fluid if that's what your brain and body need, and it responds to other hormonal signals as well, so it's a pretty complex organ. Nonetheless, there's a key point, which I already mentioned, that I think most people don't realize. This is actually something that I like to tell kids when I meet them, provided that they're of appropriate age. I'll say, oftentimes, with kids learn that I'm a scientist, they'll ask a question about something related to science, and hopefully, for my sake, it's something about neuroscience, but one thing that I'll tell kids, I'll say, "Do you know that your urine, your pee, "is actually filtered blood?" And occasionally, that will really terrify a kid, but that also occasionally really terrifies an adult, but indeed, your urine is filtered blood. Basically, blood gets into the kidney. The kidney's going to filter out certain things. Certain things are going to be allowed to pass through and others are not, okay? So the way the kidney is designed is that about 90% of the stuff that's absorbed from the blood is going to be absorbed early in this series of tubes, and only a small percentage is going to be regulated or worked out as you get into what's called the distal kidney. I mean, distal just means the furthest part away, okay? The proximal is up close, so like your shoulder is proximal to your midline of your body, and your hand is distal, so in

biological terms, you hear about proximal, distal, which just means near or far from, so just to give a really simple example, let's say that you are very low on fluid. You haven't had much to drink in a while. Maybe you're walking around on a hot day. Chances are that the neurons in your OVLT will sense the increase in osmolarity, right? The concentration of salt is going to be increased relative to the fluid volume that's circulating. This, of course, assumes that you haven't excreted a lot of sodium for one reason or another, but that increase in osmolarity is detected by the OVLT. The OVLT is going to signal a bunch of different cascades through the supraoptic nucleus, et cetera, and then, vasopressin is going to be released into the bloodstream, and vasopressin, again, also called antidiuretic hormone, is going to act on the kidney and change the kidney's function in a couple of different ways, some mechanical, some chemical, okay? In order to make sure that your kidney does not release much water, doesn't make you want to urinate, and in fact, even if you would try to urinate, your body's going to tend to hold onto its fluid stores. So very simple, straightforward example. We can also give the other example whereby if you are ingesting a lot, a lot, a lot of water, and it's not a particularly hot day, and you're not sweating very much, let's assume your salt intake is constant or is low for whatever reason, well, then, the osmolarity, the salt concentration in your blood, is going to be lower. Your OVLT will detect that because of these osmosensing neurons in your OVLT. Your OVLT will fail to signal to the supraoptic nucleus, and there will not be the release of vasopressin antidiuretic hormone, and you can excrete all the water that your body wants to excrete, meaning you'll be able to urinate. There's no holding onto water at the level of the kidney, okay? Very simple examples, but hopefully, it illustrates how events within the blood, meaning the concentration of salt relative to the amount of fluid, right? That's what osmolarity is, is detected by the OVLT. The brain then communicates to the pituitary. The pituitary sends a hormone out into the blood, and the hormone acts on the kidney to either hold onto or let go of fluid, meaning to prevent you from wanting to urinate or from stimulating you to want to urinate. Very, very simple kind of yes/no-type situation here. There's a lot of nuance to this in reality. There are a lot of other hormones in this pathway, but I think, for at least this stage of the discussion,

00:39:08 Vasopressin: Roles in Libido & Urination

this should be sufficient. Some of you may have noticed that a molecule we've been

talking a lot about today, vasopressin, was also mentioned on a previous episode of the Huberman Lab Podcast, but in a very different context. The molecule I'm referring to is vasopressin, and, as I mentioned, it's a hormone involved in antidiuresis, meaning preventing urination. It's an antidiuretic, but we also talked about vasopressin in the context of desire, love, and attachment. We talked about it in the context of monogamy and nonmonogamy in a species of animal called the prairie vole. You can check out that episode. I believe vasopressin in the nonmonogamous prairie voles are mentioned in the timestamp, so it should be easy to find. Vasopressin is made at multiple locations in the nervous system, mainly the supraoptic nucleus, and indeed, it's also involved in aspects of sexual behavior and mating. Now, it does that through mechanisms that are distinct from its antidiuretic effects. In fact, there are people who take vasopressin as an aphrodisiac. Now, I'm certainly not suggesting people do that, but I have all the confidence in the world that the moment I talk about vasopressin, someone in the comments is going to say, "What do you think about vasopressin nasal sprays "and this kind of thing?" Vasopressin, and indeed oxytocin, another hormone that's involved in pair bonding and various aspects of brain and body function, are available as nasal sprays that can get up into the deep recesses of the brain and can impact some of these core what we call hypothalamic functions, these primitive drives and hypothalamic functions. I would encourage a lot of caution, maybe even extreme caution in recreational use of things like vasopressin and oxytocin unless you are working with MD, an MD, excuse me, and they prescribe it or they really know what they're doing. These are powerful hormones that have a lot of different effects on the brain and body. The way that vasopressin, meaning antidiuretic hormone, prevents the release of fluid as urine from the body is pretty interesting. It acts directly on the kidney, so, as I mentioned before, blood flows into the kidney. A number of things are retained in the early part of the kidney. Vasopressin acts at a fairly distal, meaning kind of end game part of the loops of tubes through the kidney, and it increases the permeability of those tubes. In other words, it makes sure that the fluid that would otherwise pass into a collecting duct and then go out to the bladder never actually makes it to the bladder. I point this out because what antidiuretic hormone does is it prevents the bladder from filling at all. It's not as if it locks fluid in the bladder and prevents you from urinating. I think the way I've been describing things up until now and the way you'll hear about antidiuretic hormone, it might sound like it kind of locks up the bladder or prevents you from being able to urinate, but you have a full bladder. That would be very uncomfortable. That's not the

way it works. It actually causes the tubes headed towards the bladder from the kidney to become permeable, meaning to allow fluid to go back into the bloodstream, into the rest of the body, so that fluid never actually fills the bladder, and so you never feel the urge to urinate. Now, this is an episode about salt. A key thing to understand about the kidney is that the kidney uses sodium in order to conserve water, which has everything to do with the fact that sodium can actually hold water. Put differently, water tends to follow sodium, so where we have sodium, we tend to have water, and sodium, when it's concentrated, can hold onto water, and that's one of the main ways that the kidney holds onto water in the body, and as we'll soon learn, there is no simple and direct formula to say, for instance, "Okay, if salt levels are high, a lot of water is retained," and if salt levels are low, a lot of water is released." On the one hand, that can be true, but it's also the case because these systems are homeostatic, meaning they're always seeking balance, both within system, within the salt system, and between systems, the salt and water system. It's also the case, often, that if we have enough sodium, well, then we can secrete sodium and some water will follow, or if we don't have enough sodium, then, yes, indeed because we're not holding onto water, more fluid can be excreted, but if that condition of low sodium lasts long enough, then we start to retain water because the body recognizes, "Ah, salt is low, and water is being excreted," and eventually, a system will kick in to retain water, so I'd love to give you a simple black-and-white, yes-or-no answer for low sodium, high sodium, moderate sodium, and water balance, but it's all contextual, and when I say contextual, I mean, it will depend on blood pressure, hypertension, prehypertension, if that's there, maybe normal tension, hormone levels, exercise, et cetera, et cetera. A pretty good example of how complicated this can all be is one that some of you may be familiar with. It's pretty well known that during certain phases of the menstrual cycle, when estrogen and progesterone and other hormones are fluctuating, that water can be retained in the body. It's what's called edema, or a swelling, sometimes, so the common assumption, and indeed, it can be true, that when estrogen levels are high, there's water retention in the body. Also, in males, if estrogen levels are high, there can be water retention in the body. This is one of the reasons why athletes and, in particular, bodybuilders who take anabolic steroids like testosterone, which can be converted into estrogens, sometimes they'll look, they'll walk around, they look like they were partially inflated. They look like they're going to pop, and it looks like a swelling of the skin, not just because they have large muscles, and that's not always, but often, water retention due to testosterone conversion into estrogen. Now, that all

sounds consistent, right? Estrogen levels fluctuate in the menstrual cycle. In males, where there's an increase in estrogen, there's retention of water, but actually, estrogen acts as a diuretic, so one would think, "Okay, when estrogen levels go up, "there should be a lot of fluid excreted," but I bring up this example to point out that it's a very complicated and dynamic balance between hormones and salt and fluid. You can't draw a one-to-one relationship there, and that turns out to be a very important point, and we can use that, not as a way to further complicate things, but as a way to understand under which contexts

00:45:46 How Much Salt Do You Need?

less sodium intake or more sodium intake can be beneficial, so that's where I'd like to turn our attention now, so how much salt do we need? And what can we trust in terms of trying to guide our ingestion of salt? First of all, I want to be very, very clear that there are a number of people out there that have prehypertension or hypertension. You need to know if you have prehypertension or hypertension. You need to know if you have normal tension, meaning normal blood pressure. Everyone should know their blood pressure. It's an absolutely crucial measurement that has a lot of impact on your immediate and long-term health outcomes. It informs a lot about what you should do. Should you be doing more cardiovascular exercise? Should you be ingesting more or less salt? Should you be adjusting any number of different lifestyle factors? So you need to know that, and without knowing what your blood pressure is, I can't give a one-size-fits-all recommendation, and indeed, I'm not going to give medical recommendations. I'm simply going to spell out what I know about the research, which, hopefully, will point you in the direction of figuring out what's right for you in terms of salt and indeed fluid intake. There is a school of thought that everybody is consuming too much salt, and I do want to highlight the fact that there are dozens, if not hundreds, of quality papers that point to the fact that a, quote-unquote, high salt diet can be bad for various organs and tissues in the body, including the brain. It just so happens that because fluid balance, both inside and outside of cells, is crucial, not just for your heart and for your lungs and for your liver and for all the organs of your body, but also for your brain, that if the salt concentration inside of cells in your brain becomes too high, neurons suffer, right? They will draw fluid into those cells because water tends to follow salt, as I mentioned before, and those cells can swell. You can literally get swelling of brain tissue. Conversely, if salt levels are too

low inside of cells in any tissue of the body, but in the brain included, then the cells of the body and brain can shrink because water is pulled into the extracellular space, away from cells, and indeed, under those conditions, brain function can suffer, and indeed, the overall health of the brain can suffer, so there are many reports out there indicating, both in experimental models and, to some extent, in humans, that overconsumption of salt is bad for brain function and longevity, and yet there is also decent evidence, in both animal models and humans, that if salt consumption is too low, then brain health and longevity will suffer, as will other organs and tissues of the body, so, like most things in biology, you don't want things too high or too low. Now, I would say that the vast majority of studies out there point to the fact that a high-salt diet is detrimental to brain health and function. Most of the studies have focused on that aspect of salt balance and its consequences on brain function. One critical issue with many of those studies, however, is that the high-salt diet is often coupled to other elements of diet that are also unhealthy, things like excessively high levels of carbohydrates or fats or combinations of carbohydrates and fats, and so while I know there are many burning questions out there about how much salt one needs if they are on a low-carbohydrate diet or if they are fasting or if they are on a vegan diet, there have simply not been many studies that have explored the low, moderate, and high-salt conditions on a backdrop of very controlled nutrition, and that's probably reflective of the fact that there are not a lot of very well-controlled nutrition studies out there. There are some, of course, but it's very hard to get people to adhere to nutritional plans in a very strict way, and to do that for sufficient periods of time that would allow the various health outcomes to occur. Nonetheless, there's some interesting reports that indicate that the amount of salt intake can indeed predict health outcomes or what we call hazardous events, things like cardiovascular events and stroke and so forth, and what's interesting is that indeed a lower, I'm not saying low, right? Because I don't believe that you want your diet to be truly low in anything except, perhaps, poison, but a lower-salt diet can reduce the number of these so-called hazardous events, but it's a somewhat of a shallow U-shaped function such that, yes indeed, a high salt intake can be very detrimental for your health, both in terms of cardiovascular events, stroke, and other deleterious health events, but somewhere in the middle that actually sits quite to the right, meaning higher than what is typically recommended for salt intake, can actually reduce the number of these hazardous events, at least some reports point to that, and so I want to emphasize what one of those particular reports says, and I also want to be sure to counter it from the perspective of

the context that that study was set in because, again, my goal here is not to give you a strict set of recommendations at all. It's to point you to the literature, try and make that literature as clear as possible, and allow you to evaluate for yourself, and I don't just say that to protect us. I say that to protect you because indeed you are responsible for your health and your health choices, so the paper that I'm referring to is a very interesting one. We, of course, never want to put too much weight on any one report, but this is a paper that was published in 2011 in the "Journal of the American Medical Association." The title of the paper is "Urinary Sodium and Potassium Excretion "and the Risk of Cardiovascular Events." We have not talked much about potassium yet, but sodium and potassium tend to work in concert in the brain and body in order to regulate various physiological functions in health, and we'll talk more about potassium as time goes on. The key plot or set of data in this study, for those of you that want to look it up, we will link to it. There are a lot of data in here, but is Figure 1, which is basically evaluating the amount of urinary excretion of sodium, which is a somewhat indirect, but nonetheless valuable measure of how much sodium people were ingesting and plotted against that is what they call the hazard ratio, and the hazard ratio points to the composite of cardiovascular death, stroke, myocardial infarction, and an infarct is an injury, and hospitalization for congestive heart failure, and what it points to is the fact that the hazard ratio is low-ish at sodium excretion of about 2 grams per day, but then continues to go down until about 4.5 to 5 grams per day that, remember, this is sodium excretion, so it's reflective of how much sodium was in the body, which is reflective of how much sodium was ingested, and then, the hazard ratio increases fairly dramatically, a very steep slope, heading anywhere from 7 to 8 to 10 and out towards 12 grams of sodium excretion per day, so the simplest way to interpret these data are that at fairly low levels of sodium, meaning at about 2 grams per day, you run fewer health risks, but the number of risks continues to decline as you move towards 4 and 5 grams per day, and then, as you increase your salt intake further, then, the risk dramatically increases, so no study is holy, nor is any figure in any study or any collection of studies holy. Rather, we always want to look at what the bulk of data in a particular field reveal. Nonetheless, I think the plot that we described, meaning the graph that we described, is pretty interesting in light of the 2020 to 2025 dietary recommendations for Americans, which is that people consume no more than 2.3 grams, meaning 2,300 milligrams of sodium per day. That's about 1/2 a teaspoon of salt per day. Now, most people are probably consuming more than that because of the fact that they are ingesting processed foods,

and processed foods tend to have more salt in them than nonprocessed foods. Now, of course, that's not always the case, right? Sea salt is not a processed food, in most cases, and there are a lot of unprocessed foods that can be high in sodium, but processed foods, in particular, tend to have a lot of sodium. You can see this simply by looking at the packaging of any number of different foods, but if we are to take this number of 2.3 grams, that's the recommended cutoff for ingestion of sodium, it actually falls in a portion of the curve that we were talking about a moment ago that indeed is associated with low hazard, low incidence of hazardous outcomes, cardiovascular event, stroke, et cetera, but the ingest, according to that plot, the ingestion of 4 or 5 grams of sodium, almost double, or more sodium than is currently recommended, is associated with even lower numbers of hazardous events, so we need to think about this, and we need to explore it in the context of other studies, of course, and we need to evaluate it in terms of this thing that we've been going back to again and again, which is context, right? These recommendations of 2.3 gram per day cutoff is in the context of a landscape where some people do indeed have hypertension or prehypertension. The incidence of hypertension has gone up dramatically in the last 100 years and seems to continue to go up. Whether or not that's because of increased salt intake or whether or not it's because of increased salt intake and other things such as highly processed foods, that isn't clear, again, pointing to the challenge in doing these epidemiological studies and really parsing what aspects of a change in some health metric is due to, for instance, the ingestion of more sugars versus more salts or simply because of the ingestion of more salts. It's a complicated, almost barbed-wire topic by now, but we can start to pull apart that barbed wire tangle and start to evaluate some of the other people

00:56:45 Should You Increase Your Salt Intake?

and other conditions that exist out there, maybe for you, that actually warrant more sodium intake and where more sodium intake might actually be beneficial, so, again, I want to be very, very clear that you need to know your blood pressure. If you have high blood pressure or you're prehypertensive, you should be especially cautious about doing anything that increases your blood pressure, and, as always, you want to, of course, talk to your doctor about doing anything that could adjust your health in any direction, but nonetheless, there are some important papers that have been published in recent years. I want to point to one of them, in particular. This is a paper that was published in the

journal "Autonomic Neuroscience: Basic and Clinical" because this paper, like several other papers, asked the question, and indeed, they ask the question in the title. It's a review: "Dietary Sodium and Health: "How Much Is Too Much for Those with Orthostatic Disorders." Now, orthostatic disorders come in a bunch of different varieties, and we're going to talk about those in a moment, but there are a number of people out there that have low blood pressure, right? People that get dizzy when they stand up, people that are feeling chronically fatigued, and in some cases, not all, those groups can actually benefit from increasing their sodium intake. Several episodes ago on the Huberman Lab Podcast, I gave a, what, it's just clearly what we call anec-data, which is not even really data. It's just anecdotal data of an individual who was always feeling hungry and craving sugar, and based on the fact that they also had low blood pressure, I had them talk to a physician, and they got permission to try a little mini-experiment on themselves, and so they did, and that mini-experiment was anytime they felt like they were craving sugar or they were feeling a little lightheaded and dizzy, rather than reaching for something with caloric intake, they took a little bit of sea salt, a little pinch of sea salt, and put it into some water, and drank it, or, in the case of this individual, they would actually take a little sea salt packet, and they would actually just down a sea salt packet, and for them, that provided tremendous relief for their dizziness, but that, of course, was in the context of somewhat abnormally low blood pressure, so I don't think that they are alone in the fact that many people out there suffer from a low blood pressure condition. Many people out there suffer from a high blood pressure condition, so know your blood pressure, and understand that blood pressure, in part, is regulated by your sodium intake and your sodium balance. Why? Well, because of the osmolarity of blood that we talked about before, where if you have a certain concentration of sodium, meaning sufficient sodium in your bloodstream, that will tend to draw water into the bloodstream, and essentially, the pipes that are your capillaries, arteries, and veins will be full. The blood pressure will get up to your head, whereas some people, their blood pressure is low because the osmolarity of their blood is low, and that can have a number of downstream consequences. I should also mention it can be the consequence itself of challenges or even deficits in kidney function, but all of these organs are working together, so the encouragement here is not necessarily to ingest more sodium. It's to know your blood pressure and to address whether or not an increase in sodium intake would actually benefit your blood pressure in a way that could relieve some of the dizziness and other symptoms of things like orthostatic disorders, but, of course, to do that in a safe context

and to never play games with your blood sugar or your blood osmolarity that could set your system down a cascade of negative events. Let's look at what the current recommendations are for people that suffer from orthostatic disorders like orthostatic hypo, meaning too low, tension, orthostatic hypotension, postural tachycardia syndrome, sometimes referred to as POTS, P-O-T-S, or idiopathic orthostatic tachycardia and syncope. These have the incredibly elaborate names. Those groups are often told to increase their salt intake in order to combat their symptoms. The American Society of Hypertension recommends anywhere from 6,000 to 10,000. These are very high levels, so this is 6 grams to 10 grams of salt per day, keeping in mind, again, that salt is not the same as sodium, so that equates to about 2,400 to 4,000 milligrams of sodium per day. Again, if you want to learn more about this and get more of the citations, I'll refer you back to this study on "Dietary Sodium and Health: How Much Is Too Much for Those with Orthostatic Disorders." We'll put a link to this in the caption show notes, so that's not just in the U.S. The salt recommendations from the Canadian Cardiovascular Society are 10,000 milligrams of salt per day, so 4 grams of sodium is what that equates to, and on and on and on, for things like POTS, for these postural syndromes that result from, or I should say from these syndromes that involve low blood pressure when people stand up or in certain postures, so I point out this paper, and I point out these higher salt recommendations to emphasize, again, that context is vital, right? That people with high blood pressure are going to need certain amounts of salt intake. People with lower blood pressure, and maybe with some of these postural orthostatic syndromes, are going to need higher amounts of salt, and for most people out there, you're going to need to evaluate how much salt intake is going to allow your brain and body to function optimally, and there are some fairly straightforward ways to explore that, and there's some ways to explore that in the context of what you already know about thirst and salt appetite that can make that exploration one in which it's not going to be

01:02:19 Tools: Determining Your Individual Salt Intake

a constant wandering around in the dark and where you can figure out what's right for you. For most people, a moderate increase in salt intake is not going to be detrimental provided that you consume enough fluids, in particular, water, 'kay? Meaning if you happen to overeat salt a bit, you will get thirsty, you will ingest more water, and you will excrete the excess sodium. There is evidence that the body can store sodium in various

organs. That storage of sodium may or may not be a detrimental thing. In general, excess storage of sodium in tissues and organs of the brain and body is not thought to be good for long-term health, so eating much more sodium than you need for long periods of time is indeed bad for you. Earlier, I mentioned that salt and your hunger and thirst for salt is homeostatically regulated, and indeed, that's the case, much like temperature is homeostatically regulated. What that means is, if you pay attention to it, if your salt levels are low, you will tend to crave salt and salty beverages and salty foods, and in most cases, you should probably follow that craving provided those salty beverages and salty foods are not bringing in a lot of other things or anything, ideally, that's bad for you, so I think it's fair to say that whether or not you're vegan, vegetarian, carnivore, omnivore, that we should all try to limit our ingestion of processed foods, a'ight? My read of the literature is that, sure, some processed foods are acceptable for us and aren't going to kill us outright, but that for most people in the world, eating fewer processed foods is just going to be a good thing to do, so following your salt hunger and thirst, in most cases, is going to be beneficial provided that it's in the context of eating healthy, nonprocessed foods on whatever backdrop of nutritional and dietary recommendations is right for you. I simply can't tell you what to eat and what not to eat because I acknowledge the fact that some people are vegans because of ethical reasons related to animals, or some people are vegans because of reasons related to the climate and the environment. Other people do it for specific health reasons. Likewise, I know plenty of people that eat meat and avoid vegetables, believe it or not, and I know people that eat both, and they do this, often, each, I should say, all, citing literature that supports their particular camp and their particular view. It's not a territory I want to get into, but with respect to salt intake and the fact that salt intake is homeostatically regulated, it is the case that if you're craving salt, you probably need it, so for those of you that are sweating excessively, or even if you're in a very hot environment, and you're not exercising, and you're just losing, you're losing water and salt from your system, remember, also, that you can be in a very cold environment, very cold, dry environments often go together, and you can be losing a lot of fluids from your body, and you will crave fluids and salt even though it's cold and you're not actually noticeably perspiring, so if you're exercising a lot, if you're in a particular cold, dry environment or a particular hot environment, you ought to be ingesting sufficient amounts of salt and fluid. A rule of thumb for exercise-based replenishment of fluid comes from what I, some episodes back, referred to as the Galpin equation. The Galpin

equation, I named it after Andy Galpin, and I think that is the appropriate attribution there. Andy Galpin is an exercise physiologist at Cal State, Fullerton, I believe, and he's going to be a podcast guest here on the Huberman Lab Podcast. He's an exceptional muscle physiologist. He also lives in the practical realm where he gives recommendations about exercise to expert athletes as well as the everyday person, so the Galpin equation is based on the fact that we lose about one to five pounds of water per hour, which can definitely impact our mental capacity and our physical performance, and the reason that loss of water from our system impacts mental capacity and physical performance has a lot to do with, literally, the changes in the volume of those cells, the size of those cells, based on how much sodium is contained in or outside those cells, and something that I've alluded to before on the podcast, and I'll talk about more in a moment, which is that neurons signal to one another by way of electricity through something called the action potential, and that actually requires sodium and potassium and magnesium, so the Galpin equation suggests that we start exercise hydrated with electrolytes, not just with water, so that means water that has some sodium, potassium, and magnesium. There are simple, low-cost ways to do that we'll talk about, and the formula for hydration, the so-called Galpin equation, is your body weight in pounds divided by 30 equals the ounces of fluid you should drink every 15 minutes. That may turn out to be more fluid than you can comfortably consume during the activity that you're performing. Now, the Galpin equation is mainly designed for exercise, but I think is actually a very good rule of thumb for any time that you need to engage mental capacity, not just physical performance. Your body weight in pounds divided by 30 equals the ounces of fluid you should drink every 15 minutes does not necessarily mean you have to ingest it every 15 minutes on the dot, and I think many activities, physical activities, but also cognitive activities like Zoom meetings or in-person meetings or lecturing or running or cycling are going to make it complicated to ingest the appropriate amount of fluid every 15 minutes on the dot. I'm not going to speak for Andy, for Dr. Galpin, but I think he would probably agree that these are averages to shoot for, and that unless you're hyperneurotic, the idea is to make sure that you're entering the activity, cognitive or physical, sufficiently hydrated, and that throughout that activity, you're hydrating regularly, and it points to the fact that most people are probably underhydrating, but not just underhydrating from the perspective of not ingesting enough water, that they're probably not getting enough electrolytes as well: sodium, potassium, and magnesium, so I've said two somewhat contradictory things. On the one hand, I've

said, "Follow your salt appetite. Follow your salt thirst. If you're craving salt, ingest some salt until you stop craving the salt." On the other hand, I've given you this fairly specific recommendation based on the Galpin equation that you should ingest your body weight in pounds divided by 30. That's how many ounces of fluid you should drink every 15 minutes, which I'm guessing, for most people, is going to be more fluid than they're currently drinking, on average, and so how could it be that you can have a recommendation for what's optimal that's different than the amount that you would reflexively drink? And it has to do with the fact that a lot of the hormone systems like vasopressin antidiuretic hormone, other hormones like aldosterone, and a lot of the neural and hormonal signals that govern salt and water balance are fairly slow to kick in, so, for instance, if you eat a fairly salty meal, and you sense that salt, you'll probably, meaning you detect it and perceive it because the food tastes salty, you'll probably want to drink a fair amount of fluid with it, whereas if some of the salt is disguised by other flavors, something that we'll talk about in a few minutes when we talk about the neural representation of things like salty and sweet, well, then, you might not notice that something's salty, and then, a few minutes or hours after ingesting that meal, you might feel very, very tired. You might even wonder whether or not it's because of some blood sugar effect. Maybe it's a crash in blood sugar, you might think, or something else related to that meal, or maybe you think it's because of some other event in your life, but actually, what has happened is you're dehydrated because you didn't recognize that you needed to drink more fluids, so I want to acknowledge the contradiction in the idea that everything is homeostatically regulated, and therefore you are aware of what you need, and the counterargument that, ah, you need to follow these strict recommendations is actually going to be somewhere in between, and, of course, your body and brain can start to adapt to certain levels of salt intake. There's now a fairly famous study that was done in Germany which looked at different phases of salt intake, meaning they had subjects ingest either 12 grams of salt per day or 9 grams per day or 6 grams per day for fairly long periods of time, and they collected urine for testing. This was actually a very controlled study. I'm just going to paraphrase from the National Institutes of Health report on this study because they did a very nice write-up of it, and they say that a big surprise of these results is that whatever the level of salt that was consumed, sodium was stored and released from the subjects' bodies in fairly regular weekly and monthly patterns, meaning people tended to adapt to a certain level of salt intake, and then it led to a fairly constant amount of salt retention and urine fluid excretion, and that's because of the

various hormones, like aldosterone, which regulates sodium excretion from the kidney, and glucocorticoids, which we'll talk about more in a moment, which help regulate metabolism. Glucocorticoids are released from the adrenal glands, which ride atop the kidneys, and there's a very close relationship between the stress system glucocorticoids and the salt system, so the reason why your salt appetite isn't a perfect readout of how much salt you should ingest and why it might be helpful to follow some of these formulas like the Galpin equation, especially if you're engaging in exercise where you're going to be perspiring, of course, is that your body will tend to adapt to a certain amount of salt intake over time, and then, your appetite for salt won't necessarily be the best indication of how much salt you should ingest or avoid. Before I move on, I want to really reemphasize the fact that inside of the Galpin equation there is that mention of every 15 minutes, and people have come back to me again and again about this saying, "I can't drink that much water every 15 minutes. "It's too much volume of fluid in my stomach. "I can't run with that," et cetera. Remember, these are averages, so that's what you want to average around a particular activity. These not strict recommendations where a buzzer goes off and every 15 minutes you have to chug that exact amount of electrolyte-containing solution. Another key feature of the study that I was referring to before, which, incidentally, was published in the "Journal of Clinical Investigation," is that the body regulates its salt and water balance, not just by excreting sodium, right? But by retaining or releasing water, and this is because of the relationship between sodium and water that we were talking about before, and the advantage of this mechanism, they state, here I'm paraphrasing, is that the long-term maintenance of body fluids is dependent, is not as dependent on external water as once believed, right? What this system probably evolved to do was to adjust to different levels of sodium availability

01:14:02 Iodine, Sea Salt

in the environment, and that raises a really key element of salt and its importance in human history and human evolution and human health. Haven't talked too much about this, and there are several very good books about the history of salt. Salt was a very valuable and heavily sought-after substance throughout much of human history, so much so that there are actually written reports of people being paid for labor in the form of salt, and salt, when it's scarce, has been quite expensive in certain regions of the world, especially regions located further away from the sea, and a friend of mine who

has deep roots within the culinary community told me about traveling to some somewhat impoverished areas of Europe some years ago and going into homes where in the middle of the kitchen table, there was a fish, a salty fish hanging from a thread above the table, and that because of a lack of availability of table salt, the common practice was to take any food that needed some salt for additional flavoring and to actually rub that food on this salty fish or to squeeze the fish a bit onto the food substance in order to get salt from it, so that's a very kind of extreme example. Nowadays, we kind of take salt for granted, and most of the discussion out there is about excess salt, but, as I'm pointing out, that salt, for a long time, has been a very sought-after commodity and one that people really cherished for their health. In the episode that I did on metabolism, I talked about the relationship between salt and iodine. If you're interested in iodine and whether or not iodized salt or noniodized salt is best or required, I'd encourage you to listen to that episode, which was about, again, metabolism. Some people may need more iodine intake. Some people perhaps do not. Some people might even want to ingest things like kelp. Some people might not, so please listen to that episode if you're interested in the iodine aspects of salt, which have direct impact on thyroid hormone and thyroid function, which, of course, relates to metabolism. Nowadays, there's a lot of interest in and even a kind of proliferation of what I call fancy salts, so whether or not you should be ingesting sea salts or common, whether or not common table salt will suffice. In most cases, for what we're discussing here, common table salt is fine, but I should point out that sea salt often contains other minerals, which can be very useful, and we will do entire episodes on those other minerals, so sea salt can contain dozens or more of minerals, some of which can be quite valuable to our health, others of which are less important and only need to be consumed in trace amounts, but you're not going to get many minerals, if any, from common table salt, and that's why, in addition to the pretty colors, and, perhaps, some people report that they actually taste better, some of these so-called fancy salts or sea salts, you might want to consume a more advanced form of salt, if you will, although I suppose it's actually the more primitive form of salt

01:17:13 Salt: Roles in Stress & Anxiety

if it's actually the one that comes from the ocean, so we've all heard about how excess salt, it's bad for blood pressure, damage the heart, the brain, et cetera. I do want to give some voice to situations where too little salt can actually cause problems, and this has

everything to do with the nervous system, so without getting into excessive amounts of detail, the kidneys, as we talked about before, are going to regulate salt and fluid balance. The adrenal glands, which ride atop the kidneys, are going to make glucocorticoids, like aldosterone, and those are going to directly impact things like fluid balance, and, in part, they do that by regulating how much craving for and tolerance of salty solutions we have, and there's some really nice studies that have looked at so-called adrenalectomies. Now, this is an extreme case, and it's typically done in animal models, but it illustrates the role of the adrenals in salt preference. Basically, when the glucocorticoid system, meaning the release of these particular hormones from the adrenal glands, is eliminated by adrenalectomy, -ectomy means removal, then, the threshold for what's considered too salty really shifts, okay? So typically, when the adrenals are intact, an animal or a human will prefer a mildly salty to moderately salty solution if given a choice, and at some point, it's so salty that it just feels aversive, just like taking a gulp of seawater is almost always aversive. I can't think of an instance where it's not aversive, and actually drinking seawater can kill you because of the high osmolarity of seawater. You certainly don't want to drink seawater. Under conditions where the adrenals are missing, animals and humans will tend to prefer a higher sodium concentration fluid, and they will be willing to tolerate ingesting very high concentrations of sodium. Now, that's a very crude experiment, and not one that you want to do, I promise you, but I mention it because it illustrates the very direct relationship between the stress system, which is the glucocorticoid system, and the salt craving system, and this actually makes sense. Earlier, as we were talking about hypovolemic thirst, when there's a loss of blood pressure from, usually due to a loss of blood from the body, there's a salt craving in order to bring that blood volume back up because by ingesting salt, you bring fluid into the bloodstream. You're increasing that blood pressure, and you can restore the blood that's lost. Now, there are many examples where, if sodium levels get too low in the bloodstream, either because people are ingesting too little salt, or they're ingesting too much water and therefore excreting too much salt, that it can cause stress and anxiety. There's some really nice data that point to the fact that low dietary sodium can actually exacerbate anxiety in animal models, and to some extent, there's evidence for this in humans as well, and that should not come as a surprise. The whole basis for a relationship between the adrenal system, these glucocorticoids, things like aldosterone, and the craving for sodium is that the stress system is a generic system designed to deal with various challenges to the organism, to you or to me or to an

animal, and those challenges can arrive in many different forms. It can be an infection. It can be famine. It can be lack of water and so on, but in general, the stress response is one of elevated heart rate, elevated blood pressure, and an ability to maintain movement and resistance to that challenge, 'kay? I've said this before, but I'll emphasize it again, there's this common misperception that stress makes us sick, and indeed, if stress lasts too long, it has a number of negative effects on our health, but more often than not, if we're pushing, pushing, pushing, we're studying or taking care of somebody or traveling like crazy, we don't tend to get sick under those conditions, but as soon as we stop, as soon as we reduce our adrenaline output, as soon as we reduce our glucocorticoid output from our adrenals, then we will get sick. That's a very common occurrence, and it's because stress actually activates our immune system in the short term, so I'd like to try and dispel this myth that stress actually suppresses the immune system, at least not in the short term. For long-term stress, it's a different issue. You don't want long-term ongoing stress, especially of several weeks or more. Nonetheless, it makes sense that bringing sodium into the body would be at least one way that we would be wired to counteract or to resist stressors, right? Stressors being the things on the outside coming at us, so it could be stressful relationships, stressful job situation, again, infection, and so on. It's clear from a number of studies that if sodium levels are too low, that our ability to meet stress challenges is impaired. Now, that doesn't mean to place your sodium intake cosmically high, but it does point to the fact that if you're feeling anxious, perhaps from low blood pressure, which can also give symptoms of anxiety, as we talked about before, but even if it's independent of low blood pressure, that slightly increasing sodium intake, again, I would encourage people to do this not in the context of processed foods and drinks, but ideally, in the form of maybe a little bit of sea salt and water or salting one's food a little bit more, that that can stabilize blood pressure and one's ability to lean into stressors and challenges, and I say this because I think that most people assume that adding salt is always bad, when, in fact, that's simply not the case. There are conditions, such as when we are under stress challenge, when there is a natural craving for more sodium, and that natural craving for more sodium is hardwired into us as a way to meet that challenge, so it's hard for me to know whether or not people out there, especially the listeners of this podcast, are getting too much, just enough, or too little sodium, so I can't know that. I'm shouting into a tunnel here. You have to decide how much sodium you are ingesting, but I think that there's some, for most people, especially people who are not hypertensive, prehypertensive, there's some wiggle room to explore

whether more intake of sodium could actually be beneficial for suppressing some of the anxiety responses that they might feel under conditions of stress. Again, more studies need to be done. Certainly, more studies in humans need to be done, but the relationship between stress and sodium intake and the fact that additional sodium intake may be beneficial and indeed, is naturally stimulated by stress shouldn't be necessarily looked at as a pathological event. I know when some people get stressed, they crave salty foods. That's actually a hardwired biological phenomenon that you see, not just in humans, but in animals,

01:24:20 Other Electrolytes: Magnesium & Potassium

because this is a very primitive mechanism whereby your body is preparing to meet any additional challenges and stressors. Now, we can't have a discussion about sodium without having a discussion about the other electrolytes, magnesium and potassium. Magnesium is important enough and an extensive enough topic that we should probably do an entire episode just on magnesium. For purposes of today's discussion, I just will briefly touch on some of the forms of magnesium that we've discussed on the podcast before in different contexts. I want to emphasize that many people are probably getting enough magnesium in their diet that they don't need to supplement magnesium. Some people, however, opt to supplement magnesium in ways that can support them, and there are many different forms of magnesium, and just in very brief passing, I'll just say that there is some evidence that you can reduce muscle soreness from exercise by ingestion of magnesium malate, M-A-L-A-T-E. I've talked before about magnesium threonate, T-H-R-E-N-O-A-T-E, magnesium threonate, for sake of promoting the transition into sleep and for depth of sleep and perhaps, again, highlighted perhaps, 'cause right now it's mainly animal studies and ongoing human studies, but the data aren't all in. Perhaps magnesium threonate can be used as a way to support cognitive function and longevity. That was discussed in the episode with Dr. Jack Feldman from UCLA. Typically, magnesium threonate is taken 30 to 60 minutes before bedtime in order to encourage sleep. You can go to our neural network newsletter and look for the one on sleep, and you can see the recommendations, or I should say, the options for that because, again, you should always check with your physician. Those aren't strict across-the-board recommendations, and then, there are other forms of magnesium: magnesium bisglycinate, which is a somewhat of an alternative to threonate, not known

to have cognitive enhancing effects, but seems, at least on par with magnesium threonate in terms of promoting transition into and depth of sleep and so on. There are other forms of magnesium, magnesium citrate, which has other functions. Actually, magnesium citrate is a fairly effective laxative, not known to promote sleep and things of that sort, so a lot of different forms of magnesium, and there's still other forms out there. Many people are not getting enough magnesium. Many people are. Okay, that's magnesium. Anytime we're talking about sodium balance, we have to take into consideration potassium because the way that the kidney works and the way that sodium balance is regulated, both in the body and the brain, is that sodium and potassium are working in close concert with one another. There are a lot of different recommendations about ratios out there, and they range widely from two-to-one ratio of potassium to sodium. I've heard it in the other direction too. I've heard a two-to-one sodium to potassium. The recommendations vary. One of the sponsors of this podcast, for instance, LMNT, which I've talked about in this episode and before, the ratio there is a gram of sodium to 200 milligrams of potassium, 60 milligrams of magnesium, so there, they've opted for a five-to-one ratio of sodium to potassium, and, of course, many people opt to make their own hydration electrolyte formulas. They'll put sea salt into some water, maybe even ingest a potassium tablet. It all depends on the context, and an important contextual element is your diet, so, for instance, carbohydrates hold water in the body, so regardless of how much salt and how much fluid you're ingesting,

01:27:57 Tools: Effects of Low-carbohydrate Diets & Caffeine

if you're ingesting carbohydrate and you drink fluids, water, some of that fluid is going to be retained in the body. Now, for people that are following low-carbohydrate diets, one of the most immediate effects of a low-carbohydrate diet is that you're going to excrete more water, and so, under those conditions, you're also going to lose not just water, but you'll probably also lose sodium and potassium, and so some people, many people, in fact, find that when they are on a lower or low-carbohydrate diet, then they need to make sure that they're getting enough sodium and enough potassium, and some people do that by taking 99-milligram potassium tablets every time they eat. Some people do that by ingesting more foods that contain potassium, and, of course, some people who are on low-carbohydrate diets do ingest vegetables or other forms of food that carry along with them potassium, so it's quite variable from person to person. I mean, you can

imagine if carbohydrate holds water, water and salt balance and potassium go hand in hand, and hand, that if you're on a low-carbohydrate diet, that you might need to adjust your salt intake and potassium, and conversely, that if you're on a carbohydrate-rich diet or a moderate carbohydrate diet, then you may need to ingest less sodium and less potassium, and, in fact, a certain amount of water is probably coming in through the foods you eat as well, so I don't say all this to confuse you. Again, I say this because it all depends on the context. I'll give yet another context that I think is fairly common nowadays, which is many people are following a pattern of eating that more or less resembles intermittent fasting or at least time-restricted feeding, so they're eating between particular feeding windows, and then, in the certain parts of the 24-hour cycle, not just sleep, but during certain parts of their waking cycle, they're also actively avoiding food, banking on, I think, either the possible, I want to say possible, longevity-promoting effects of intermittent fasting, or, and/or, I should say, they are banking on the fact that for many people, not eating is easier than portion control for certain parts of the day, and so they find it beneficial to limit calories overall to a given amount, depending on what their goals are, by not consuming food for certain periods of the day, but usually, during those periods of the day, they're consuming fluids, and oftentimes, those fluids include not just water, but caffeine, and caffeine is a diuretic. It actually causes the excretion of fluids from the body in part, because it causes the excretion of sodium. All of that to say that if you're somebody who, for instance, eats your first meal around noon or 1:00 or 2:00 p.m., and you're fasting for the early part of the day, and you're drinking coffee or tea or ingesting a lot of water, you are going to be excreting sodium along with that water, and so many people, including myself, find that it's useful, especially when I'm drinking caffeine during that so-called fasting or nonfood intake part of time-restricted feeding, that I'm making sure to get enough salt, either in the form of something like LMNT, an electrolyte drink, or putting some sea salt into some water, or certainly, anytime one is ingesting caffeine, replacing some of the lost water by increasing one's water intake. There are some simple rules of thumb around this that I think can get most people into a place where they're more comfortable and functioning better, which is for every ounce of coffee or tea that you drink, I should say caffeinated coffee or tea that you drink, that you consume 1 1/2 times as much water, so let's say you have an 8-ounce coffee, try and drink about, you don't have to be exact, but try and drink about a 12-ounce glass of water, and you might want to put a tiny bit of sodium into that. By tiny bit, I just mean a tiny pinch of sodium because remember, even if we're talking about

increasing the amount of sodium intake overall, the total amount of sodium contained in salt is sufficiently high that even just 1/4 teaspoon is going to really start to move that number up towards that range that's still within the safe range, but you're going to, if you keep doing that all day long, you're very quickly going to get into that excessive salt intake range that is deleterious for health, so again, if you're consuming more caffeine, you're going to be excreting water and salt and potassium, and so you're going to have to find ways to bring water, salt, and potassium back in. Again, this has to be evaluated for each of your own individual situations. If you're exercising fasted, and you're doing that after drinking caffeine, then before, during, and certainly after exercise,

01:32:28 General Recommendations for Salt Intake

you're going to want to replenish the fluids and electrolytes that you lost, including sodium, so you can imagine how this all starts to become pretty dizzying, and yet it doesn't have to be dizzying. We can provide some useful ranges that, for most people, will work, and so let's talk about what those ranges are, and I'm going to point you to a resource that explores what those ranges are in these various contexts of nutrition, exercise, and so on. The resource is a book that was authored by Dr. James DiNicolantonio. He's not a medical doctor. He's a scientist, so he's cardiovascular physiology as well, I believe, as a doctor of pharmacy, and the title of the book is "The Salt Fix." "The Salt Fix" is an interesting read because it points to, first of all, the history of salt in society and as it relates to health. It actually emphasizes some of the major missteps, maybe even pretty drastic errors, that have been made in terms of trying to interpret the role that salt has in various diseases and emphasizes some of the ways in which, perhaps, increasing salt can actually improve health outcomes, and I think it strikes a pretty nice balance between what's commonly known about salt and what I believe ought to be known about salt, or at least taken into consideration. The book does provide certain recommendations, and I actually reached out to the author. I've never met him in person or talked to him directly, and I asked him outright. I said, "How much salt "do you recommend people take on average?" And he gave, of course, the appropriate caveats about prehypertension, hypertension, et cetera, but made a recommendation which I'll just share with you, and if you want to learn more about the support for this recommendation, you can check out his book. The recommendation he made was anywhere from 8 to 12 grams of salt a day, which corresponds to 3.2 to 4.8

grams of sodium, so going back to the current recommendations that we talked about before, 2.3 grams of sodium per day, this is about 1 1/2 times to double the amount of sodium that's currently recommended in most circles, and then, what this corresponds to is about 1 1/2 to 2 teaspoons of salt per day to arrive at that 3.2 to 4.8 grams of sodium. Again, this is the recommendation that was passed along for most people, most conditions, barring specific health issues. Now, what was also interesting is he pointed to a sodium-to-potassium ratio, which is 4 grams of potassium, and he also mentioned 400 milligrams of magnesium, and pointed out, and I generally agree here, that many people are deficient in magnesium, so again, that was a 3.2 to 4.8 grams of sodium, 4 grams of potassium. You might think, "Well, gosh, "that's 1 1/2 to 2 times the current recommendation," but we can go back to that study that was mentioned earlier in the episode, that 2011 study, where I describe this sort of J-shaped curve in which, when you look at the occurrence of these negative health events, they were fairly low at low sodium intake, lower still at slightly higher sodium intake, much in line with the recommendations that are made or that Dr. DiNicolantonio passed along to me, and then, they increased quite, those health risks increased quite substantially as one moves out past 6 grams of sodium, 7 grams of sodium per day. That's when things really do seem to get hazardous, and really, it makes sense, I think, given the consensus around this, to really avoid very high salt intake, so "The Salt Fix" describes the rationale behind those recommendations. "The Salt Fix" also describes, in quite beautiful detail, the relationship between salt intake, potassium intake,

01:36:34 Perception of Salt & Sugar Taste, Processed Foods

and the relationship to the sugar consumption system. I'd like to pick up on this idea of the relationship between salt and sugar because I think that one key aspect of the way that salt can work and can benefit us or can harm us has to do with the way that sodium and sugar are regulated and actually perceived by the brain and how, under conditions of certain levels of sodium intake, we might be inspired to seek more sugar or to crave sweets more or less, so up until now, we've been talking about salt as a substance and a way to regulate fluid balance and blood volume and so on. We haven't talked a lot about salt as a taste or the taste of things that are salty, and yet we know that we have salt receptors, meaning neurons, that fire action potentials when salty substances are detected, much in the same way that we have sweet detectors and bitter detectors, and

we have detectors of umami, the savory flavor, on our tongue, and earlier, at the beginning of the episode, I talked about the fact that we have sweet receptors, neurons that respond to the presence of sugar or even noncaloric sweet things in the gut, and that signals up to the brain through the vagus nerve, and those signals converge on pathways that relate to dopamine and so on. Well, we also have salt sensors at various locations throughout our digestive tract, although the sensation and the taste of salt actually exerts a very robust effect on certain areas of the brain that can either make us crave more or sate, meaning fulfill, our desire for salt, and you can imagine why this would be important. Your brain actually has to register whether or not you're bringing in salt in order to know whether or not you are going to crave salt more or not, and beautiful work that's been done by the Zuker Lab, Z-U-K-E-R, Zuker Lab at Columbia University, as well as many other labs have used imaging techniques and other techniques such as molecular biology to define these so-called parallel pathways, parallel meaning pathways that represent sweet or the presence of sweet taste in the mouth and gut, parallel pathways, meaning neural circuits that represent the presence of salty tastes in the mouth and gut and so on, and that those go into the brain, move up through brain stem centers and up to the neocortex indeed where our seat of our conscious perception is to give us a sense and a perception of the components of the foods that we happen to be ingesting and a sense and a perception of the fluids and the components of those fluids that we happen to be ingesting. Now, parallel pathways, as I'm describing them, are a fundamental feature of every sensory system, not just the taste system, but also the visual system. We have parallel pathways for perceiving dark objects versus light objects, for perceiving red versus green, et cetera. This is a fundamental feature of how we are built and how our nervous system works, and in the taste system, much like in these other systems, these pathways are indeed parallel, but they converge, and they can influence one another, and I think the simplest way to put this is in the context, first, of the visual system, whereby your ability to detect the color red has everything to do with the fact that you have neurons in your eye that absorb long wavelengths of light that we call reds, red wavelengths of light, which are longer wavelengths than, say, blue light, which are shorter wavelength, but it is really the comparison of the electrical activity of the neurons that absorb red light with the activity of the neurons that absorb green light which actually gives you the perception of red, so that might seem a little counterintuitive, but indeed, it's not. It's actually because something is red and has less greenness that we perceive it as more red than the green,

and this is actually the way that your entire nervous system works is that we aren't really good at evaluating absolute levels of anything in the context or perception. It's only by comparison, and actually, there's a fun experiment that you can do, I think you could probably find it easily online, but you could also do this experiment at home. You can stare at something that's red, or green, for that matter, for a while, so you make an active decision to not blink and to stare at something that's red, and then you look away from that thing, and you'll actually see a green afterimage of that red object. Conversely, if you look at something that's green for a while, and you stare at it, and you look away, you will see the red afterimage of that thing. Now, the taste system doesn't have quite the same aftertaste type effect, but nonetheless, the pathways, the parallel pathways for salty and the parallel pathways for sweet and bitter and so on can actually interact, and this has important relevance in the context of food choices and sugar craving. One of the things that's commonplace nowadays is in many processed foods there is a business, literally, a business of putting so-called hidden sugars, and these hidden sugars are not always in the form of caloric sugars. They're sometimes in the form of artificial sweeteners into various foods, and you might say, "Well, "why would they put more sugar into a food "and then disguise the sugary taste "given that sweet tastes often compel people "to eat more of these things?" Well, it's a way, actually, of bypassing some of the homeostatic mechanisms for sweet, even though we might think that the more sweet stuff we eat, the more sweet stuff we crave, in general, people have a threshold whereby they say, "Okay, I've had enough sugary stuff." You can actually experience this. If you ever feel like something is really, really sweet, take a little sip of water with a little bit of lemon juice in it or vinegar, and it will quickly quench that overly sweet sensation or perception. It will disappear almost immediately. There's actually a practice in fancy meals of cleansing the palate through the ingestion of different foods, and that's the same idea that you're cleansing the palate. You're actually neutralizing the previous taste so then they can bring yet another dish to overindulge you in decadence and so forth, so these sensory systems interact in this way. By putting sugars into foods and hiding the sugary taste of those foods, those foods, even if they contain artificial sweeteners, can activate the sorts of neurons that we talked about at the beginning of the episode, like the neuropod cells that will then signal to the brain to release more dopamine and make you crave more of that food, whereas had you been able to perceive the true sweetness of that food, you might have consumed less, and indeed, that's what happens, so these hidden sugars are kind of diabolical. Why am I talking

about all of this in the context of an episode on salt? Well, as many of you have probably noticed, a lot of foods out there contain a salty-sweet combination, and it's that combination of salty and sweet which can actually lead you to consume more of the salty-sweet food than you would have if it had just been sweet or it had just been salty, and that's because both sweet taste and salty taste have a homeostatic balance, so if you ingest something that's very, very salty, pretty soon your appetite for salty foods will be reduced, but if you mask some of that with sweet, well, because of the interactions of these parallel pathways, you somewhat shut down your perception of how much salt you're ingesting, or conversely, by ingesting some salt with sweet foods, you mask some of the sweetness of the sweet foods that you're tasting, and you will continue to indulge in those foods, so salty-sweet interactions can be very diabolical. They can also be very tasty, but they can be very diabolical in terms of inspiring you to eat more of a particular food than you would otherwise if you were just following your homeostatic salt or your homeostatic sugar balance systems, and the beautiful imaging work that's been done by the Zuker Lab and other labs has actually been able to reveal how some of this might work by showing, for instance, that a certain ensemble, meaning a certain group of neurons, is activated by a sweet taste and a nonoverlapping distinct set of neurons just nearby sitting cheek-to-jowl with those other neurons would be activated by salty tastes and yet others by bitter taste et cetera, so there's a separate map of these different parallel pathways, but that when foods or fluids are ingested that are both salty and sweet, you get a yet entirely different ensemble of neurons activated, so your brain, whether or not it's for your visual system or your auditory system or your taste system, has a way of representing the pure form of taste, salty, sweet, bitter, et cetera, and has a way of representing their combinations, and food manufacturers have exploited this to large degree. I mention all of this because if you're somebody who's looking to explore either increasing or decreasing your sodium intake for health benefits, for performance benefits, in many ways, it is useful to do that in the context of a fairly pure, meaning unprocessed food intake background, whether or not that's key to a carnivore, omnivore, intermittent fasting, or what have you. It doesn't really matter, but the closer that foods are to their basic form and taste, meaning not large combinations of large amounts of ingredients and certainly avoiding highly processed foods, the more quickly you're going to be able to hone in on your specific salt appetite and salt needs, which, as I've pointed out numerous times throughout this episode, are going to vary from person to person depending on nutrition, depending on activity, depending on hormone status, or even

portion of your menstrual cycle, for that matter, so if you want to home in on the appropriate amount of sodium for you, yes, blood pressure is going to be an important metric to pay attention to as you go along, and the parameters for healthy blood pressure ranges are readily available online, so I'll let you refer to those in order to determine those for yourself, but in determining whether or not increasing your salt intake might be beneficial, for instance, for reducing anxiety a bit or for increasing blood pressure to offset some of these postural syndromes where you get dizzy, et cetera, for improving sports performance or cognitive performance, I can only recommend that you do this in a fairly clean context where you're not trying to do this by ingesting a bunch of salty foods or salty-sweet foods, et cetera, and indeed, many people find, and it's reviewed a bit, and some of the data are reviewed in the book "The Salt Fix," that when people increase their salt intake in a backdrop of relatively unprocessed foods, that sugar cravings can indeed be vastly reduced, and that makes sense given the way that these neural pathways

01:47:13 Role of Sodium in Neuronal Function, Action Potentials

for salty and sweet interact. Now, thus far, I've already covered quite a lot of material, but I would be completely remiss if I didn't emphasize the crucial role that sodium plays in the way that neurons function. In fact, sodium is one of the key elements that allows neurons to function at all, and that's by way of engaging what we call the action potential. The action potential is the firing of electrical activity by neurons. Now, neurons can engage electrical activity in a number of different ways. They have graded potentials. They have gap junctions. There's a whole landscape of different electrophysiologies of neurons that I don't want to go into just yet, at least not in this episode, but the action potential is the fundamental way in which neurons communicate with one another. They're sometimes called spikes. It's just kind of nomenclature that neuroscientists use. I'm just going to briefly describe the action potential and the role that sodium plays, and this will involve a little bit of chemistry, but I promise it will be accessible to anyone, even if you don't have a chemistry or a physics background or electrophysiology background. Neurons have an inside and an outside, and inside are things like your genetic material. They have a bunch of things floating around in there that allow those cells to function, and they tend to have this wire extending out of them, sometimes a very long wire, sometimes a short one, that we call the axon, and at the

end of that wire, that axon, they release little packets of chemicals that either cause the next neuron to fire action potentials or prevent the next neuron from firing action potentials, so they kind of vomit out these little packets of chemicals that either inspire or suppress action potentials in other neurons. The way that that whole process occurs is that a given neuron needs to change its electrical activity, so normally, neurons are hanging out, and they have what we call a negative charge, and the reason they have a negative charge is that the inside of the cell has things floating around in it like potassium, a little bit of sodium, and some stuff like chloride. These are literally just, just imagine these as little balls of stuff, and if they have a negative charge on them, then the inside of the cell is going to tend to be more negative, and outside of the cell, it turns out, you're going to have a bunch of stuff that's positively charged, and one of the main factors in creating that positive charge is sodium. Sodium carries a positive charge, so you have neurons that you can just imagine a, for sake of this discussion, you can just imagine as a sphere with a little wire sticking out of it. You can put a little minus on the inside for negative. You can put a little plus on the outside for positive, and when that neuron is stimulated by another neuron, if the stimulation, the electrical stimulation is sufficiently high, meaning enough little packets of neurotransmitter have been vomited onto its surface at sufficient concentration, what happens is little pores, little spaces, little gaps open up in the membrane of that cell that separates the inside from the outside, and because it's positive, there's a lot of positive charge outside, and there's a lot of negative inside, it's like a boulder running downhill. All the stuff tends to rush downhill. It tries to create even amounts of charge, so it's negative on the inside, positive on the outside, and what happens is sodium rushes into the cell carrying a lot of charge into the cell, and as a consequence, the charge of that cell goes from negative, actually, very negative, to quite positive, and if it hits a certain threshold of positive charge because of all the sodium ions going into the cell, then it fires what's called an action potential, and it vomits out its own set of chemicals onto the next neuron, and so it sets off a chain of one neuron goes from negative to positive, blech, vomits out chemicals onto the next one. The next one, the next neuron, that binds to receptors or enters the cell, and that cell goes from negative to positive charge, [imitates vomiting] vomits its contents onto the next cell, and so on and so forth. Sodium rushing into the cell, therefore, is the way that the action potential is stimulated. In other words, sodium is the way that neurons communicate with one another. Now, the neurons don't stay in a positive charge. Otherwise, they would just keep vomiting out their contents, [imitates vomiting], but they

need to maintain some of that, and they need to go back to preparing to do it the next time and the next time by resting a bit, and turns out that the way they restore their charge is by pushing that sodium back out of the cell. There are mechanisms in place to do that, things like the so-called sodium-potassium pump. There's a change in the levels of the potassium across the cell membrane and so on and so forth. If you want to look at a demonstration of this, you can just, you can put into a web browser the action potential. You'll find some beautiful descriptions there on YouTube and elsewhere. Maybe some time on Instagram, I'll do a description with a diagram 'cause I realize number of people are just listening to this. I can't do that here. I won't do that here 'cause I want everyone to be able to get the same amount of material regardless of whether or not they're watching and/or listening to this, but the point I'd like to make, at least as it relates to this episode on salt, is that having sufficient levels of salt in your system allows your brain to function, allows your nervous system to function at all. Again, this is the most basic aspect of nervous system function, and there are cases where this whole system gets disrupted, and that brings us to the topic of sodium and water balance. As many of you have probably heard,

01:53:13 Dehydration

but hopefully, if you haven't, you'll take this message seriously, if you drink too much water, especially in a short amount of time, you can actually kill yourself, right? And we certainly don't want that to happen. If you ingest a lot of water in a very short period of time, something called hyponatremia, you will excrete a lot of sodium very quickly, and your ability to regulate kidney function will be disrupted, but in addition to that, your brain can actually stop functioning, so people have actually consumed water to excess, especially after sports events and so forth, and if that water doesn't contain sufficient electrolytes, you can actually shut down neurons' ability to function at all by disrupting this balance of sodium and potassium and the amount of extracellular sodium and neurons' ability to signal to one another through action potentials, and I can't emphasize the importance of action potentials enough. They are the way that I can lift my pen right now. They're the way that I can speak. They're the way that you breathe. They literally control all aspects of your nervous system function. Now, it takes quite a lot of water intake before you excrete enough sodium that your nervous system is going to shut down, and I certainly don't want to give the impression that simply by ingesting more

sodium, your neurons will work better, but it absolutely is the case that if you don't ingest enough sodium, that your neurons won't function as well as they could, and that if your sodium levels are made too low by hemorrhage or by ingesting so much water, fluid, that you excrete excess amounts of sodium or through any other mechanism, that is, then indeed your neurons won't be able to fire action potentials and your brain and nervous system simply won't work, and that's one of the primary reasons why dehydration leads to confusion and dizziness and lack of coordination, and I've talked about this a bit in the episode on endurance, but there are instances in which competitive athletes have come into the stadium to finish a final lap of a long endurance race and are completely disoriented and actually can't find their way to the finish line. It might sound like kind of a silly, crazy example, but there are examples of people having severe mental issues and physical issues post-exercise when that exercise involved a ton of sweating or hot environments or insufficient ingestion of fluids and electrolytes because included in the electrolyte formula, of course, is sodium,

01:55:36 What Salt Intake is Best for You?

and as you just learned, sodium is absolutely crucial for neurons to function, so to briefly recap some of what I've talked about today, we talked about how the brain monitors the amount of salt in your brain and body and how that relates to thirst and the drive to consume more fluid and/or salty fluids. We also talked a little bit about the hormones that come from the brain and operate at the level of the kidney in order to either retain or allow water to leave your system. Talked a little bit about the function of the kidney itself, a beautiful organ. We talked about the relationship between salt intake and various health parameters and how a particular range of salt intake might be optimal, depending on the context in which that range is being consumed, meaning depending on whether or not you're hypertensive, prehypertensive, or normal tension. We talked about fluid intake and electrolyte intake, so sodium, potassium, and magnesium in the context of athletic or sports performance, but also, in terms of maintaining cognitive function. Talked about the Galpin equation, which you could easily adapt to your body weight and to your circumstances. Of course, adjusting the amount of fluid and electrolyte intake upwards if you're exercising or working in very hot environments, downwards, maybe, if you're in less hot environments where you're sweating less and so on. We also talked about the relationship between the stress system and the salt craving system and why

those two systems interact and why, for some people who may suffer a bit from anxiety or under conditions of stress, increasing salt intake, provided it's done through healthy means, might actually be beneficial. We also talked about conditions in which increasing salt intake might be beneficial for offsetting low blood pressure, and some of these postural syndromes that can lead people to dizziness and so forth. These are things that have to be explored on an individual basis, and, of course, have to be explored with the support of your doctor. I mentioned "The Salt Fix," which I think is an interesting read, keeping in mind that a lot of the information in there runs counter to the typical narrative that you hear around salt, but nonetheless, has some very interesting points that you might want to consider and certainly will broaden your view of the history of and the applications of salt as it relates to a great number of health and performance metrics. We also talked about the perception of salt, meaning the perception of salty tastes and how the perception of salty tastes and the perception of other tastes, like sweet, can interact with one another to drive things like increased sugar intake when you're not even aware of it, and indeed, how the combination of salty and sweet taste can bias you towards craving more, for instance, processed foods, and why that might be a good thing to avoid, and, of course, we talked about salt and its critical role in the action potential, the fundamental way in which the nervous system functions at all, so my hope for you, in listening to this episode, is that you consider a question, and that question is what salt intake is best for you? And that you place that question in the context of your fluid intake, you place that in the context of the diet you're following, the amount of caffeine you might be ingesting, and the diuretic effects of caffeine, and crucially, that you place that in the context of the electrolytes, more generally, meaning sodium, potassium, and magnesium. Someday, there will be an online program or an app, I imagine, where one could put a bunch of different parameters in about their particular health status, their particular diet, their particular exercise, et cetera. Maybe it would all be run by AI algorithm or something where it would monitor all of that for us, and then it would spit out for us a precise amount of sodium that we should take in each day. Unfortunately, no such tool or device exists right now, and so all of us have to figure out the appropriate amount of sodium intake for ourselves, and that has to be done under these contextual considerations. Who knows? Maybe one of you will design such an app or such a device. I think it would be very useful. If nothing else, today's discussion ought to illuminate the fact that some strict recommendation of salt intake cannot be made universally across the board for everybody. There's just simply no way that could be

done, and yet, I think most of what we've learned about salt in the general discussions around health are that it's this evil substance. Nothing could be further from the truth. It's an incredible substance. Our physiology is dependent on it. Our cognition is dependent on it. Indeed, our mental and physical health and our performance in essentially all aspects of life is dependent on it, and I hope I've been able to illuminate some of the beautiful ways in which the brain and the bodily organs interact in order to help us regulate this thing that we call sodium balance, and the fact that we have neurons in our brain that are both tuned to the levels of salt in our body and positioned in a location in the brain that allows them to detect the levels of salt in our body and to drive the intake of more or less salt and more or less fluid and other electrolytes really just points to the beauty of the system that we've all evolved that allows us to interact with our environment

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and make adjustments according to the context of our daily and ongoing life. If you're learning from and/or enjoying this podcast, please subscribe to our YouTube channel. That's a terrific zero-cost way to support us. In addition, please subscribe to the podcast on Spotify and/or Apple and on Apple, you have the opportunity to leave us up to a five-star review, and you can also leave us a comment. The best place to leave us comments, however, is on the YouTube channel. There, you can make suggestions about future podcast guests that you'd like us to interview, future podcast topics that you'd like us to cover, and, of course, you can give us feedback about the content of this or other podcasts. We do read all those comments. Please also check out our sponsors mentioned at the beginning of today's episode. That's the best way to support this podcast. We also have a Patreon. It's patreon.com/andrewhuberman, and there you can support the podcast at any level that you like. During today's episode, and on many previous episodes of the Huberman Lab Podcast, we discuss supplements. While supplements aren't necessary for everybody, many people derive tremendous benefit from them for things like enhancing sleep and focus and so on. One issue with supplements, however, is that the quality of supplements varies tremendously from one brand to the next. For that reason, we've partnered with Thorne, T-H-O-R-N-E, because Thorne supplements are of the absolute highest quality in terms of the ingredients they

include and the precision of the amounts of the ingredients they include, meaning what's listed on the bottle is what's actually contained in that product. They've partnered with all the major sports teams and with the Mayo Clinic, so trust is very, very high with respect to the quality of Thorne products. If you'd like to see the Thorne supplements that I take, you can go to Thorne, that's thorne.com/u/huberman, and you can get 20% off any of those Thorne supplements. In addition, if you navigate deeper into the Thorne site through that portal, thorne.com/u/huberman, you can also get 20% off any of the other supplements that Thorne makes. If you're not already following Huberman Lab on Instagram and Twitter, please do so. There, I cover science and science-based tools that sometimes overlaps with the content of this podcast, but sometimes is distinct from the content of this podcast. We also have a "Neural Network" newsletter. The "Neural Network" newsletter comes out once a month. It is zero cost. You sign up for it by providing your e-mail. We do not share your e-mail with anybody. The privacy policy is made very clear, and you can sign up for the "Neural Network" newsletter by going to hubermanlab.com, just going to the menu, scroll down to "Neural Network," and you can sign up, and even without signing up, you can access some of the previous newsletters if you'd like to see what they are like. We include short summaries from podcasts, some key takeaways, and some resources and tools that you won't find anywhere else. Thank you once again for joining me today to discuss the neuroscience and the physiology around salt and its many incredible influences on our brain and body, and last, but certainly not least, thank you for your interest in science. [authoritative music]