Welcome to the Huberman Lab podcast where we discuss science and science-based tools for everyday life. I'm Andrew Huberman and I'm a professor of neurobiology and ophthalmology at Stanford School of Medicine. 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. Today's episode of the Huberman Lab podcast is our fourth and final episode in this month, which is all about skills and athletic performance. Now, in a previous episode, we talked about science-based, in particular, neuroscience-based tools for accelerating fat loss. Previous to that, we talked about ways to improve skill learning, motor movements, which also included things like music and piano playing, not just athletic performance. And we've also been exploring other aspects of physical performance throughout the entire month. Today, I want to talk about something that is vitally important for not just athletic performance, but for your entire life and indeed for your longevity. And that's muscle. Now, many of you, when you hear the word muscle, think muscle growth and building big muscles. And while we will touch on muscle hypertrophy, muscle growth today, and science-based protocols to enhance hypertrophy, we will mainly be talking about muscle as it relates to the nervous system. And I can't emphasize this enough. The whole reason why you have a brain is so that you can move. And one of the things that's exquisite and fantastic about the human brain is that it can direct all sorts of different kinds of movement, different speeds of movement, movement of different durations. We can train our musculature to lift heavier and heavier objects, or we can train our musculature to take us further and further, so-called endurance. We can also build smoothness of movement, as well as speed of movement, suppleness of movement. All of that is governed by the relationship between the nervous system, neurons, and their connections to muscle. So when you hear the science of muscle and muscle hypertrophy, you might think, well, I'm not interested in building muscle. But muscle does many critical things. It's important for movement, it's important for metabolism. The more muscle you have, and not just muscle size, but the quality of muscle, that's a real thing. The higher your metabolism is, and indeed the healthier you are. It turns out that jumping ability, and ability to stand up quickly and to get up off the floor quickly, is one of the most predictive markers of aging and biological aging, and no surprise, that is governed by the brain to muscle connection. In addition, muscle and musculature is vital for posture, and we don't talk about posture enough. We all have been told we need to sit up straight or stand up straight, but posture is vitally important for how the rest of our body works. It's vital to how we breathe, it's actually even vital to how alert or sleepy we are. We're going to talk about the musculature for posture. We also are going to talk about muscle as it relates to aesthetic things. Now these are all linked. Muscle for metabolism, movement, posture, and aesthetics, of course are linked, right? As our posture changes are aesthetic changes, as our posture and aesthetic changes, how we move changes, and as we improve muscle quality, whether or not that's increasing muscle size or not, that changes the way that our entire system, not just our nervous system and our muscular system, but our immune system and the other organs of the body work. Today, as always, we're going to talk a little bit of mechanism. I'm going to explain how neurons control muscle, and then we're going to look at muscle metabolism, how muscle uses energy. I promise to make all of this very simple, I'm actually going to keep it very brief, probably about 10 minutes total, and by the end of that 10 minutes, you will understand a lot about the neuromuscular connection, how your brain and nervous system control your muscle, and how those muscles work. Then we are going to talk about how muscles use energy and can change how they use energy for sake of getting stronger, if you like, for also increasing the size, so-called hypertrophy of muscle, and for improving endurance, as well as for improving posture and how you move generally. We will touch on some nutritional themes and how that relates to muscle, in particular, a specific amino acid that if it's available in your bloodstream frequently enough, and at sufficient levels can help you build and improve the quality of muscle. And we'll talk about specific exercise regimes, as well as, of course, supplementation and things that can enhance neuromuscular performance overall. We are also going to talk about recovery. Recovery, as everybody knows, is when things improve. That's when neurons get better at controlling muscle, that's when muscle grows, that's when muscle gets more flexible. None of that actually happens during training, it happens after training. And there is a lot of confusion about how to optimize recovery and how to measure whether or not you are recovered and ready to come back in for another neuromuscular training session. We'll talk about that as well. Today is going to have a lot of protocols, and you're going to come away with a lot of understanding about how you move, how you work, and these incredible organs that we call the nervous system and the musculature, the so-called neuromuscular system. Before we dive into today's topic, I want to just take about three minutes and cover some essential summary of the previous episode. In the previous episode, we talked about fat loss. We talked about shiver-induced fat loss. We talked about meat, non-exercise activity, thermogenesis for increasing caloric burn and fat oxidation. And we talked about how to use cold specifically to enhance fat loss. I described a protocol involving getting into cold of some sort, whether or not it's ice bath, cold shower, some form of cold. It could even be a river or an ocean if you have access to that and inducing shiver and then getting out, not crossing your arms or huddling, but allowing that cold to evaporate off you and continuing to shiver and then getting back into the colder environment of water or stream or shower, etc. All of that is described in a beautifully illustrated protocol that I didn't illustrate. That's why it's beautifully illustrated at the coldplunge.com. They've made that protocol for you and they've made it available free of charge for you. So there's no obligation there of any kind financially. You can go to the coldplunge.com. There's a little tab that says protocols and you can download that protocol. Someone there, I don't know who exactly illustrated it and you can come away with a PDF of what I described in the previous episode. So I just want to make sure that you are aware of that resource. The other announcement I'd like to make is that many of you have asked how you can help support the podcast and there's a very straightforward zero-cost way to do that. And that's to subscribe to our YouTube channel. So if you go to YouTube, if you're not already there watching this now, hit the subscribe button. That helps us tremendously to get the word out more broadly about the podcast and we thank you for your support. Most people, when they hear the word muscle, they just think about strength. But of course, muscles are involved in everything that we do. They are involved in speaking. They are involved in sitting and standing up. They are involved in lifting objects, including ourselves. They are absolutely essential for maintaining how we breathe. They are absolutely essential for ambulation, for moving and for skills of any kind. So when we think about muscle, we don't just want to think about muscle, the meat that is muscle, but what controls that muscle and no surprise what controls muscle is the nervous system. The nervous system does that through three main nodes of control, areas of control. And I've talked about these before on a previous podcast. So I will keep this very brief. Basically, we have upper motor neurons in our motor cortex. So those are in our in our skull. And those are involved in deliberate movement. So if I decide that I'm going to pick my pen and up and put it down, which is what I'm doing right now, my upper motor neurons were involved in generating that movement. Those upper motor neurons send signals down to my spinal cord where there are two categories of neurons. One are the lower motor neurons and those lower motor neurons send little wires that we call axons out to our muscles and cause those muscles to contract. They do that by dumping chemicals onto the muscle. And the chemical is acetylcholine. I've talked before about acetylcholine in the brain, which is vitally important for focus and actually can gait neuroplasticity, the brain's ability to change in response to experience. But in the neuromuscular system, acetylcholine released from motor neurons is the way the only way that muscles can contract. Now, there's another category of neurons in the spinal cord called central pattern generators or CPGs. And those are involved in rhythmic movements. Anytime we're walking or doing something where we don't have to think about it to do it deliberately, it's just happening reflexively that central pattern generators and motor neurons. Anytime we're doing something deliberately that the top down control, as we call it, from the upper motor neurons comes in and takes control of that system. So it's really simple. You've only got three ingredients. You've got the upper motor neurons, the lower motor neurons, and for rhythmic movements that are reflexive, you've also got the central pattern generators. So it's a terrifically simple system at that level. But what we're going to focus on today is how that system can control muscle in ways that make that system better. Now, when I say better, I want to be very specific. If your goal is to build larger muscles, there's a way to use your nervous system to trigger hypertrophy, to increase the size of those muscles. And it is indeed controlled by the nervous system. So you can forget the idea that the muscles have memory or that muscles grow in response to something that's just happening within the muscle. It's the nerve to muscle connection that actually creates hypertrophy. I'll talk exactly about how to optimize that process. In addition, if you want to improve endurance or improve flexibility or suppleness or explosiveness, that is all accomplished by the way that the nervous system engages muscles specifically. So what that means is we have to ask ourselves, are we going to take control of the upper motor neurons, the central pattern generators, or the lower motor neurons, or all three in order to get to some end point of how the nervous system controls muscle. So neurophysiology 101, I'll give you one piece of history because it's important to know. Sherrington, who won the Nobel Prize, called movement the final common path. Why did he say that? Well, the whole reason for having a nervous system, the whole reason for having a brain is so that we can control our movements in very dedicated ways. That is one of the reasons, perhaps the predominant reason why the human brain is so large. You might think, oh, it's so large for thinking and for creativity. Ah, no, when you look at the amount of real estate in the brain that's devoted to different aspects of life, it's mainly vision, our ability to see, and movement, our ability to engage in lots of different kinds of movements, slow movements, fast movements, explosive, etc. Other animals don't have that ability because they don't have the mental real estate, they don't have the neural real estate in their brain. They have neuromuscular junctions, they have central pattern generators, where they don't have, are these incredible upper motor neurons that can direct activity the muscles in very specific ways. So we can all feel blessed that we have this system, and today I'm going to teach you how to use that system toward particular end points. So if we decide that we are going to direct our muscles in some particular movement of any kind, whether or not it's a weightlifting exercise or whether it's a yoga movement or simply picking up and putting down a pen, we are engaging flexors and extensors, and our body is covered with flexors and extensors all over. So for instance, our bicep is a flexor and our tricep is an extensor, those are what are called antagonistic muscles. They move the limbs in opposite directions. So if you bring your wrist closer to your shoulder, that's flexion, using your bicep, if you move your wrist further away from your shoulder, that's extension using your tricep. And without getting into a lot of detail, the way that the nerves and brain are wired up to muscle make it such that when a flexor is activated, when the nerve dumps chemical, acetylcholine onto the muscle to activate the biceps, the triceps is inhibited. It's prevented from engaging. There are ways to bypass this, but that's the typical mode of action. The converse is also true when our tricep is in activated, when we move our wrist away from our shoulder, our bicep is inhibited. And we have flexors like our abdominal muscles and we have extensors in our lower back. Many of you probably know this, but some of you probably don't that your spine has flexors to move basically your chin toward your waist, and it has, those are your abdominal muscles. Among others, and you have extensors that move your chin basically back, like looking up toward the ceiling, and those are your extensors. You have other muscles that are stabilizing muscles and things of that sort, but those movements of flexion and extension and the fact that they are what we call, reciprocally integrated or mutual inhibition, you hear different language around this, is characteristic of most of our limb movements. So hamstring and quadricep, the hamstring brings the ankle closer back towards the glutes, basically it's lifting your heel up, which is almost always done toward the back. Whereas your quadricep is the extensor opposite to the hamstrings, so you get the idea. So there's flexors and extensors, and it's the neurons that control those flexors and extensors that allow us to move in particular ways. So now you have heard neuromuscular physiology in its simplest form, but I do want this to be accessible. I want to get just briefly, just briefly, into some of the underlying metabolism of how muscles use and create energy, because in doing that, we will be in a great position to understand all the tools that follow about how to optimize the neuromuscular system for your particular goals. So in the previous episode about fat loss, we talked about light polices, the breakdown of fat into fatty acids, so it can be used as fuel, and it ended in a step where we got ATP, which is the bottleneck and the final common path for all energy producing functions in the body. There are other ways, but basically ATP is the key element there. Now with muscles, they don't function on fats, normally what they are going to function on, their ability to move, and their ability to do things and allow us to move in any way that we want to is based on a process of glycolysis, the breakdown of things like glycogen and glucose into energy. And it's a very simple process. You don't have to know any chemistry. So if I say the words carbon or hydrogen or something like that, don't freak out. You don't have to understand any chemistry. But basically what happens is you've got this available sugar resource that's stored in muscle. And that's glucose. And that glucose has six carbons and six and six waters basically. That can be broken down into two sets of three carbons. All right. So basically you take glucose and you break it into these two little batches of carbons that we call pyruvate. So six divided by two is three. So you get three and three pyruvates. And that generates a little bit of ATP of energy, but just a little bit. Now if there's oxygen available, okay, if there's sufficient oxygen there, what can happen is that pyruvate can be brought to the mitochondria. And through a whole set of things that you probably don't want to hear about right now, like the electron transport chain and citric acid cycle, what happens is it's broken down and you get 28 to 30 ATP, which is a lot of ATP. So the only things you need to know, the only things you need to know about this process is that glucose and glycogen are broken down into pyruvate. You get a little bit of energy from that. And when I say energy, I mean the ability to move. It's fuel literally just gets burned up. But if there's oxygen available and that's key, then within the mitochondria, you can create 28 to 30 ATP, which is a lot of ATP. Now what does this mean? This means that movement of muscle is metabolically expensive. And indeed, compared to other tissues, compared to fat, compared to bone, compared to almost all other tissues except brain tissue, muscle is the most metabolically demanding, which is why people who have more muscle relative to adipose tissue to fat, they can eat more and they're more of a furnace. So they just kind of burn that up. Okay. So even if you didn't understand anything that I just said, what you probably did here and that I hope you heard is that if you have oxygen around, you can create energy from this fuel source that we call glycogen and glucose. But what if there isn't oxygen around? And what is that like? Well, you've experienced that. I'm not talking about oxygen in the environment. I'm talking about oxygen in the muscle. So if you've ever carried a box while moving or you were carrying heavy groceries to the car or you were exercising particularly hard and you felt the burn, well that burning, which most people think is lactic acid, is actually a process by which pyruvate, which as I said before, normally could be converted into ATP. If there's oxygen, well, if there's not enough oxygen, because that muscle is working too hard or too long, what ends up happening is that a hydrogen molecule comes in there and you get something called lactate. So believe it or not humans don't make lactic acid. That's another species. We make lactate. And we think and we hear that lactate is bad. We need to buffer the burn or avoid the burn that lactic acid and lactate are what prevent us for performing as well as we ought to be able to or for going as far as we possibly could in an endurance event. Guess what? That's not true at all. Lactic has three functions, all of which are really interesting and really important. First of all, it's a buffer against acidity. You don't want muscle to get to acidic because it can't function. You don't want anybody to shoot to get to acidic. So that burn that you feel is acidity in that environment that and lactate, what most people call lactic acid, but again we don't make lactic acid. Lactic is there to buffer that to reduce the amount of burn. So most people have this exactly backward. So when you feel that burn that is not lactic acid. That is lactate that's present to suppress the burn to suppress acidity. It's also a fuel. When you feel that burn, lactate is shuttled to those areas of the muscle and there's an actual fuel burning process where in the absence of oxygen you can continue to generate muscular contractions. Now this is informative because it also tells us that that burning, that acidity that we feel can inhibit the way that our muscles work, but that lactate comes in and allows our muscles to continue to function. So we'll talk a little bit more about what this whole lactate thing in the burn means, but it's a really important process and it's amazing to me that most people understand it in exactly the incorrect way. They think lactic acid is bad and the burn is bad. No, it reveals a number of really important things are going on with this vital molecule lactate which can reduce acidity, reduce the burn as well as act as a fuel. Now here's where it gets really, really cool. And if you don't have enough of an incentive to exercise based on all the information out there about how it'll make you live longer and make your heart better, et cetera. Here's a reason that regardless of what kind of exercise you do, if it's weight training or running or cycling or swimming, that every once in a while, about 10% of the time, you should exercise to the point of intensity where you start to feel that so called burn. Right. The reason for that is that lactate shows up to the site of the burn, so to speak, and it acts as a hormonal signal for other organs of the body in a very positive way. Okay. As you may recall from a very early episode of the Uberman lab podcast, I talked about what a hormone is and how it works. There's lots of different kinds of hormones, but hormones are chemicals that are released in one location in the body and travel have effects on lots of other organs of the body. So when I say that lactate acts as a hormonal signal, what I mean is that it's in a position to influence tissues that are outside of the muscle. And basically, it can send signals to the heart, to the liver, and to the brain, and it can have effects on the heart, the liver, and the brain that are very positive. Okay. So just to zoom out for a second, I promise we won't get any more technical than this. We will get into tools and protocols that are really straightforward. But what I'm telling you is that if you feel a burn from a particular exercise or movement, that burn is going to be buffered by this molecule we call lactate. Lactate will then provide additional fuel for additional work. So this is a good incentive provided you can do it safely to quote unquote work through the burn. You are, that burn is a, acts as a beacon to the lactate which comes in and allows you to do more work. It's not a signal to stop necessarily. You can stop if you're doing something unsafe, but it's a signal that lactate should come in and allow you to continue to do work. And it can act as a hormonal signal. Lactate can then travel to the heart and to the liver and to the brain, and can enhance their function in positive ways, not just in those moments, but in the period of time that follows. So many people are curious about how they can exercise to make their brain better. That's one of the most common questions I get. What I'm telling you is that provided you can do it safely by engaging the so-called burn, which is a different threshold for everybody, right? Your, your hill run will be different than my hill run to generate the burn, but provided you can do that for about 10% of your workouts or of an individual workout or activity of any kind. You are generating the activity of this lactate based hormonal signal that can improve the function of neurons. And it does that if you want to know for the aficionados by improving the function of another cell type called the astrocytes, which are a glial cell type, which are very involved in clearance of debris from the brain. They're involved in the formation of synapses, connections between neurons in the brain. So put simply if you're an exorciser, if you're doing movement of any kind and you're interested in allocating some of that movement toward enhancing brain, heart, and liver health, there is a nice set of scientific data that points to the fact that getting lactate shuttled to the muscles by engaging this burning sensation is advantageous for the health of those other tissues. So as I mentioned, that burn is present from lack of oxygen being present. And then the hydrogen comes in and you get this lactate. But this process of lactate acting as a buffer, a fuel, and a positive hormonal signal for other tissues occurs only if there's oxygen. So if you feel the burn, you definitely want to focus on your breathing at that point. That would be the time to take deep inhales and try and bring more oxygen into your system. It's definitely not a time to hold your breath. And if ever you've run to the point of feeling the burn and then you were exercised in any way on the treadmill or on the bike or whatever and felt that burn and then you held your breath, it feels much more intense. By breathing, you bring lactate to the site and you are able to allow lactate to act more as a buffer, a fuel, and a hormonal signal. And the reason I brought this up today is because as I mentioned, so many people are interested in using exercise not just for sake of improving physical health and well-being and performance, but also for enhancing their brain. And there are a lot of data out there speaking to the findings that exercise of various kinds can increase neurogenesis, the creation of new neurons. Well, the unfortunate news is that while that's true in mice, there is very little evidence for enhanced neurogenesis from exercise or otherwise in humans. There's a little bit and there are a few sites within the brain such as the dentate gyros of the hippocampus, which may be involved in the formation of new memories. To be clear, the dentate gyros is definitely involved in the formation of new memories, whether or not the new neurons that are added there in humans are involved in new memories. And the evidence for that is weak at best, frankly, whereas in animals that the data are quite strong. But most of the data point to the fact that hormonal signals, things that are transported in the blood during exercise are what are beneficial for the brain, excuse me. And that those signals are not causing the increase in the number of neurons in the dentate gyros or otherwise, that it's more about the health of the connections between the neurons, growth factors of various kinds, things like IGF1, there's a long list of these things. So if you've heard the exercise increases the number of neurons in your brain, well, that's not true. And that probably is a good thing, frankly, because we always hear more neurons, more neurons as if it's a good thing. But the brain doesn't do so well with bringing in entirely new elements. It has a hard time negotiating that and making use of those new elements. We know about this from things like the cochlear implant where deaf people are given a device where they suddenly can hear. Some people really like that. Deaf people really like that and can benefit from it. Other deaf people find that it's very intrusive. That it's hard to take an existing neural circuit in the brain and incorporate a lot of new information into it. So new neurons, as great as that sounds, more neurons, more neurons. It actually might not be the best way for the nervous system to change and modify itself and to promote its own longevity. So when I tell you, you know, not such great evidence from a new neurons past puberty, that's what the data really show in humans. And I sort of knock back the data on exercise and neurogenesis. Don't let that depress you. If you have dimension in your family, don't translate that into a necessarily that you will develop dementia. Understand that exercise is still beneficial for the brain and other aspects of the nervous system, but that it's going to be doing it through these hormonal signals, things like IGF1, things like this lactate pathway, when you experience the burn from exercise. And again, you don't want to try and get this feeling of a burn throughout the entire episode of exercise. There will be far too intense and when it inhibits your recovery, I don't think it'll be good for performance either. It's only about 10% of your total effort in any one exercise bout that's going to give you this positive effect. So now you know how to devote a small portion of your exercise, 10% in order for muscle and lactate to benefit other tissues, namely your heart, your liver, and your brain. I now like to shift our attention to how to use specific aspects of muscular contraction to improve muscle hypertrophy, muscle growth, as well as improving muscle strength. There are a lot of reasons to want to get stronger. And I should just mention that it's not always the case that getting stronger involves muscles getting bigger. There are ways for muscles to get stronger without getting bigger. However, increasing the size of a muscle almost inevitably increases the strength of that muscle, at least to some degree. Reasons why most everyone should want to get their muscles stronger is that muscles are generally getting progressively weaker across the lifespan. So when I say getting stronger, it's not necessarily about being able to move increasing amounts of weight in the gym, although if that's your goal, what I'm about to discuss will be relevant to that. But rather to offset some of the normal decline in strength and posture and the ability to generate a large range of movements safely that occurs as we age. So I mentioned the beginning of the episode, we just tend to lose function in this neuromuscular system as we get older. And doing things to offset that has been shown again and again to be beneficial for the neuromuscular system, for protection of injury, for enhancing the strength of bones and bone density. So there are a lot of reasons to use resistance exercise that extend far beyond just the desire to increase muscle size. Because I know many of you are interested in increasing muscle size, but many of you are not. So there's an important principle of muscle physiology called the henimin size principle. And the henimin size principle essentially says that we recruit what are called motor units. Motor units are just the connections between nerve and muscle from a in a pattern that staircases from low threshold to high threshold. What this means is when you pick up something that is light, you're going to use the minimum amount of nerve to muscle energy in order to move that thing. Likewise, when you pick up an object that's heavy, you're going to use the minimum amount of nerve to muscle connectivity and energy in order to move that object. So it's basically a conservation of energy principle. Now, if you continue to exert effort of movement, what will happen is you will tend to recruit more and more motor units with time. And that process of recruiting more neurons, more lower motor neurons, as if you recall from the beginning of the episode, these lower motor neurons are in our spinal cord and they actually dump a chemical, see it, calling it a muscle, cause the muscles to contract. As you recruit more and more of these motor units, these connections between these lower motor neurons and muscle, that's when you start to get changes in the muscle. That's when you open the gate for the potential for the muscles to get stronger and to get larger if that's what your goal is. And so the way this process works has been badly misunderstood in the kind of online literature of weight training and bodybuilding and even in sports physiology. The Heneman-Size principle is kind of a foundational principle within muscle physiology. But many people have come to interpret it by saying that the way to recruit high threshold motor units, the ones that are hard to get to, is to just use heavy weights. And that's actually not the case. As we'll talk about, the research supports that weights in a very large range of sort of percentage of your maximum anywhere from 30 to 80%. So weights that are not very light but are moderately light, too heavy, can cause changes in the connections between nerve and muscle that lead to muscle strength and muscle hypertrophy. Put differently. Heavy weights can help build muscle and strength, but they are not required. What one has to do is adhere to a certain number of parameters, just a couple of key variables that I'll spell out for you. And if you do that, you can greatly increase muscle hypertrophy, muscle size, and or muscle strength if that's what you want to do. And you don't necessarily have to use heavy weights in order to do that. Now I'm sure the power lifters and the people that like to move heavy weights around will say, no, if you want to get strong, you absolutely have to live heavy weights. It might be true if you want to get very strong, but for most people who are interested in supporting their muscular such that they offset any age related decline in strength or an increasing hypertrophy and strength to some degree, they really isn't a need to lie about the henimin size principle, which many people out there are doing, and claiming that you absolutely need to use the heaviest weights possible in order to build strength and muscle. So, first of all, let's just talk about what hypertrophy is and what strength changes in the muscle are. We can make this very simple as well. If this were a muscle physiology class, we would talk all about, you know, myocybrals and sarcom mirrors and all that stuff. We're not going to do that. That's not the purpose of today's conversation. If you're interested in that, as well as a lot of the other information that I'm going to discuss in more detail, I highly encourage you to check out the YouTube channel from and the writings of Dr. Andy Galpin. He's a PhD and a full professor in exercise physiology. He's extremely knowledgeable in this entire area of science based tools for hypertrophy, how strength and hypertrophy really work. His lab does everything from biopsy on muscles, working with athletes and typical folks as well. A lot of the information that you're going to hear from me in the next 15 minutes or so comes from an extensive exploration of the work that he and his colleagues have done as well as folks like Brad Shownfield, another academic who's superb in this whole space of muscle physiology. And from a lengthy conversation that I had with Andy, Dr. Galpin, prior to this episode. So if we want to think about muscle hypertrophy, we have to ask what is changing when muscles get larger or stronger? And there are really just three ways that muscles can be stimulated to change. So let's review those three ways and talk about what happens inside the muscle. So there are three major stimuli for changing the way that muscle works and making muscles stronger, larger or better in some way. And those are stress, tension and damage. Those three things don't necessarily all have to be present, but stress of some kind has to exist. Something has to be different in the way that the nerve communicates with the muscle and the way that the muscle contracts or performs that makes the muscle need to change. So this is very reminiscent of neuroplasticity in the brain. Something needs to happen. Certain chemicals need to be present. Certain processes need to happen or else a tissue simply won't change itself. But if those processes and events do happen, then the tissue has essentially no option except but to change. So muscles move, as I mentioned, because nerves dump chemical onto the muscles, but they move because they have these things called myosin and actin filaments. And if you want to read up on this, you can look on the internet. You can put the sliding filament theory of muscle contraction if you really want to go deep down that rabbit hole. It's interesting. You can learn about this in a muscle physiology class. But basically along the length of the muscle, you have what's called myosin. And just think of myosin as kind of like a wire. It's like a bunch of beads and wires that extend across the muscle. I think that's the simplest way to describe it. And the myosin is surrounded by these little beads called actin. The way muscles get bigger is that basically the myosin gets thicker. It's a protein, right? And it gets thicker. So put this in your mind. If you're listening to this or even if you're watching it on YouTube, the way to think about this whole actin myosin thing and muscles getting bigger is imagine that you're holding a bouquet of balloons, a bunch of balloons by their strings. Except you're not holding the strings all at their bottom. So the bouquet isn't nicely arranged. It's not like some balloons that are all up at the top and you're holding the strings down at the bottom. Imagine that one of the balloons that is very close to your hand, another one is a little bit higher up. And so this bouquet is very disorganized. In other words, the string extending out of your hand, the strings rather extending out of your hand are all different lengths. And so the balloons are all over the place. That's essentially what myosin looks like in the muscle. And those strings are what we call the filaments. And then the myosin head that is the balloon. When you stress a muscle properly or you give it sufficient tension or you damage the muscle just enough, there's an adaptive response that takes place where protein is synthesized and it's a very specific protein, it's myosin, the myosin gets thicker. In other words, the balloons get bigger. So the way to think about muscle growth and the way to think about muscles getting stronger is that those balloons get bigger and the muscle gets thicker. Now the question then should be, as always, how does that happen? I mean, the muscle doesn't really know anything about what's happening in the outside world. The way it happens is the nerve, the neuron has to tell the muscle to get stronger. And it does that through what we call a signaling cascade. It talks to the muscle in terms of chemicals. It doesn't whisper to it or shout out, hey, get bigger. What it does, it releases certain chemicals that within the muscle, there are certain chemicals released rather that make those balloons as I'm referring to them, the myosin gets thicker. So let's talk about the stimulus for doing that. And if already in your mind you're imagining, oh my goodness, these balloons of muscle are going to get thick, thick, thick, thick. And it's just going to spiral out of control. Don't worry about that. People invest a ton of time and energy into trying to make their muscles larger. It's actually much harder for people to do than you might think. But I do want to give one exception because it illustrates an important principle of where we're headed next. Everybody has imbalances in how muscles can grow. How well muscles can grow or how poorly or how challenging it is for their muscles to grow. Now, many people who are afraid of like getting too bulky, for instance, are afraid of lifting weights. But I think the research shows now that every one of pretty much every age should be doing some sort of resistance exercise, even if that's body weight exercises in order to offset this age related decline in muscle contractile ability, muscle strength, et cetera, improve bone density. And nothing good about getting frail and weak over time. And people who invest the effort into doing resistance exercise of some kind, whether or not with bands or with weights or with body weight really benefit tremendously at a whole body level, at a systemic level, as well as in terms of muscle strength. And there is a good predictor of how well or how efficient you will be in building the strength and or if you like the size of a given muscle. And it has everything to do with those upper motor neurons that are involved in deliberate control of muscle. You can actually do this test right now. You can just kind of march across your body mentally and see whether or not you can independently contract any or all of your muscles. So for instance, if you are sitting in a chair or you're standing, see whether or not you can contract your calf muscle, just using those upper motor neurons, sending a signal down and deliberately isolating the calf muscle. If you can contract the calf muscle hard to the point where that muscle almost feels like it's starting to cramp like it hurts just a little bit, you know, it might not can be extremely painful nor is it going to have no sensation whatsoever. Chances are you have very good upper motor neuron to calf control. And chances are if you can isolate that what they call that brain or mind muscle connection and you can contract the muscles to the point where it cramps a little bit. That you hold a decent to high potential to change the strength and the size of that muscle if you train it properly. Now if you have a hard time doing that, chances are you won't be able to do that. If for instance you focus on your your back muscle like we all have these muscles called the latissimus dorsi muscles which basically are involved in chin ups and things like that. But their function from a more of a kinesiology standpoint is to move the elbow back behind the body. So it's not about flexing your biceps, it's about moving your elbow back behind your body. If you can do that mentally or you can do that physical movement of moving your elbow back behind your body and you can contract that muscle hard, chances are that you have the capacity to enhance the strength and or size of that particular muscle because you have the neural control of that muscle. This is a key feature of the neuromuscular system to appreciate as we begin to talk more about specific protocols because everything about muscle hypertrophy, about stimulating muscle growth is about generating isolated contractions, about challenging specific muscles in a very unnatural way. Whereas with strength it's about using musculature as a system moving weights, moving resistance, moving the body. The specific goal of hypertrophy is to isolate specific nerve to muscle pathways so that you stimulate the chemical and signaling transduction events in muscles so that those muscles respond by getting larger. So there's a critical distinction in terms of getting stronger versus trying to get muscles to be larger hypertrophy per se and it has to do with how much you isolate those muscles. Muscle isolation is not a natural phenomenon, it's not something that we normally do when we walk we don't think okay right calf contract, left calf contract. No, you just generate those rhythmic movements and of course there's no reason for them to get stronger or larger in response to those movements. Let's say you were to do a kind of strange experiment of attaching 30 pound weights to your ankles and you were to do those movements. Well if you weren't specifically contracting your calves in each step, there's no reasons for the calves to take on the bulk of the work and you would distribute that work across your hip flexors and other aspects of your musculature. Your whole nervous system seeks to gain efficiency, it seeks to spread out the effort. So you can nest this as a principle for yourself, which is if you want to get stronger, it's really about moving progressively greater loads or increasing the amount of weight that you move. Whereas if you're specifically interested in generating hypertrophy, it's all about trying to generate those really hard, almost painful localized contractions of muscle. Now of course how much weight you use in order to generate those contractions will also impact hypertrophy. But I think most people don't really understand the mind muscle connection, it sounds like a great thing, but it's actually one of the things you want to avoid if your goal is simply to become more supple or to become stronger. You want to do the movements properly and safely, of course, but it's the opposite of hypertrophy where with hypertrophy, you're really trying to make that particular muscle, sometimes two muscles, do the majority, if not all the work. Whereas in moving forslodes, in trying to generate activity of any kind, like lifting a bar or doing a chin up or something, those so-called compound movements that involve a lot of muscle groups. If your goal is to be better at those, you want to avoid isolating any one particular muscle. Now I know this probably comes across as a kind of an obvious duh, especially to the folks that spent a lot of time in the gym aimed at getting hypertrophy. But I think most people don't appreciate that it's the nerve to muscle connections and the distinction between isolating nerve to muscle connections versus distributing the work of nerve to muscle connections that's vital in determining whether or not you generate hypertrophy, isolated nerve to muscle contractions versus strength and offsetting strength loss, which would be distributed nerve to muscle connections. If ever there was an area of practical science that was very confused, very controversial and almost combative at times, it would be this issue of how best to train. I suppose the only thing that's even more barbed wire of a conversation than that is how best to eat for health. Those seem to be the two most common areas of online battle. The scientific literature has a lot to say about both of those things. Again, my sources for what I'm about to tell you are Professor Andy Galpin and colleagues. I know there are other excellent people out there in the field, but I really trust his work. He does very controlled studies. He spends a lot of time in this space. What's really exciting is that in just the last three years or so, it's been a tremendous amount of information to come out about the practical steps that one can take in order to maximize the benefits of resistance exercise of any kind. I'm going to talk about those and I'm going to talk about the research. I will provide some links, both to a couple of the more in-depth tutorials from Dr. Galpin, as well as some of the papers that the information I'm about to tell you stems from. There's a lot of information saying that you need to move weights that are 80 to 90% of your one maximum or 70% or cycle that for three weeks on and then go to more moderate weights. There are a lot of paths. As some people say, there are a lot of ways to add up numbers to get 100. There's a near infinite number of ways to add up different numbers to get to 100. What's very clear now from all the literature that's transpired, especially from the literature in this last three years, is that once you know roughly your one repetition maximum, the maximum amount of weight that you can perform and exercise with for one repetition in good form, full range of motion, that it's very clear that moving weights or using bands or using body weight, for instance, in the 30 to 80% of one rep maximum, that is going to be the most beneficial range in terms of muscle hypertrophy and strength. And there will be a bias. If you're moving weights that are in the 75% 80% range or maybe even going above that 85% and 90% you're going to bias your improvements towards strength gains. This is true. And if you use weights that are in the 30% of your one repetition maximum or 40% or 50% and doing many more repetitions, of course, then you are biasing towards hypertrophy and what some people like to call muscle endurance, but that's a little bit of a complicated term because endurance, we almost always think of as relating to running or swimming or some long bouts of activity. So 30 to 80% of one repetition maximum, it doesn't really seem to matter for sake of hypertrophy, except at the far ends when you're really trying to bias for strength. Now, it is clear, however, that one needs to perform those sets to failure where you can't perform another repetition in good form again or near to failure. And there's all sorts of interesting nomenclature that's popping up all over the internet, some of which is scientific, some of which is not scientific about how you are supposed to perceive how close you were to failure, et cetera. But there are some very interesting principles that relate to how the nerves connect to the muscles that strongly predict whether or not this exercise that you're performing will be beneficial for you or not. So here's how it goes, for individuals that are untrained, meaning they have been doing resistance to exercise for anywhere from zero, probably out to about two years, although for some people it might be zero to one year, but those are the so called beginners, they're sort of untrained. For those people, the key parameter seems to be to perform enough sets of a given exercise per muscle per week. Okay, the same is also true for people that have been training for one or two years or more, what differs is how many sets to perform depending on whether or not you're trained or untrained. So let's say you're somebody who's been doing some resistance exercise kind of on and off over the years, and you decide you want to get serious about that for sake of sport or offsetting age related declines in strength. The range of sets to do in order to improve strength to activate these cascades in the muscle ranges anywhere from two believe it or not to 20 per week again, these are sets per week and they don't necessarily all have to be performed in the same weight training session. I will talk about numbers of sessions. So it appears that five sets per week in this 30% to 80% of the one repetition maximum range getting close to failure or occasionally actually going to full muscular failure, which isn't really full muscular failure, but the inability to generate a contraction of the muscle and move the weight in good form. I'll go deeper into that in a moment, but about five sets per week is what's required just to maintain your muscle. So think about that. If you're somebody who's kind of a verse to resistance training, you are going to lose muscle size and strength, your metabolism will drop, your posture will get worse. Everything in the context of nerve to muscle connectivity will get worse over time unless you are generating five sets or more of this 30% to 80% of your one repetition maximum per week. So what this means is for the typical person who hasn't done a lot of weight training, you need to do at least five sets per muscle group. Now that's just to maintain and then there's this huge range that goes all the way up to 15 and in some case 20 sets per week. Now how many sets you perform is going to depend on the intensity of the work that you perform. This is where it gets a little bit controversial, but I think nowadays most people agree and Dr. Galpin confirmed that 10% not to be confused with the 10% we discussed earlier, but 10% of the sets of a given workout or 10% of workouts overall should be of the high intensity sort where one is actually working to muscular failure. Now I say not true muscular failure because in theory you have a concentric movement which is the kind of lifting of the weight and then you have the eccentric portion of muscle contraction which is the lowering and eccentric movements because of the way that muscle fibers lengthen and that sliding act in myusin that we talked about before, you're always stronger in lowering something than you are in lifting it. The point being that most of your training, most of your sets should be not to failure and the reason for that is it allows you to do more volume of work without fatiguing the nervous system and depleting the nerve to muscle connection in ways that are detrimental. So we can make this simple, perform anywhere from 5 to 15 sets of resistance exercise per week and that's per muscle and that's in this 30 to 80% of what your one repetition maximum. That seems to be the most scientifically supported way of offsetting any decline in muscle strength if you're working in the kind of 5 set range and in increasing muscle strength when you start to get up into the 10 and 15 set range. Now the caveat to that is everyone varies and muscles vary in terms of their recoverability. Depending on how well you can control the contraction of muscles deliberately and you can actually figure that out by sort of marching, you might take 5 minutes and just kind of march across your body and mentally try and control the contractions of muscles in a very deliberate way to the point where you can generate a hard contraction and you may have to move a limb in order to do this by the way. I'm not talking about just mentally contracting your bicep without moving your wrist. I'm talking about doing that without any weight in hand or any band or any resistance. If you can generate a high intensity contraction using these upper motor neuron to lower motor neuron pathways to muscle, you might think, well, I should perform many more sets. But actually the opposite is true. If you can generate high intensity muscular contractions using your brain, using your neurons, it will take fewer sets in order to stimulate the muscle to maintain itself and to stimulate the muscle in order to grow or get stronger. So the more efficient you are in recruiting motor units, remember, Hennamen's size principle, the recruitment of more motor units, which isn't just muscles, it's nerve to muscle connections. The better you are at doing that, the more you will recruit these so-called high threshold motor units, the ones that are hard to get to, the more you will kick off the cascades of things within muscle that stimulate muscle growth and strength. So if you have muscles that are challenging to contract, it's going to take more sets in order to stimulate the desired effect in those muscles, not fewer. If you have muscles that you are very good at generating force within, it's going to take fewer sets. Now, how many sets you are going to have to determine that? It's going to depend for those of you that are using like 50% of your one repetition maximum, because you're doing a lot of repetitions, you might find that three or four, five sets will maintain the muscle, you might decide to do that once at one point in the week and then do it again. So if you're going for 10 sets a week, you can divide that among two sessions, so you can do that all in one session. The data really show it doesn't matter. There are some differences in terms of whether or not you're trying to generate maximum intensity within a workout or whether or not you want to spread that out. But in general, resistance workouts of any kind tend to be best favored by workouts that are somewhere between 45 minutes and 60 minutes. Generally, not longer than 60 minutes, because that's when all the things like cortisol and some of the inflammatory pathways really start to create a situation in the muscle and in the body that's not so great for you. So it's not a hard and fast rule, you know, that the ax doesn't drop at 60 minutes, but it's pretty clear that performing this five to 15 sets per week, whether or not it's in one workout or whether it's divided up across multiple workouts, is really what's going to be most beneficial. So you do keep in mind, Hennamen's size principle and the recruitment of motor units, and remember the better you are at contracting particular muscles in isolating those muscles, the fewer sets likely you need to do in order to get the desired effect. Now what about people who have been training for a while, if you're somebody who's been doing weight training for a while, the data point to the fact that more volume can be beneficial, even for muscles that you are very efficient at contracting. The curve on this, the graph on this, begins again at about five sets per week for maintaining a given muscle group and extends all the way out to 25 or 30 sets per week. However, there are individuals who, for whatever reason, can generate so much force, they're so good at training muscles that they can generate so much force in just four or six or eight sets that doing this large volume of work is actually going to be counterproductive. So everyone needs to figure out for themselves, first of all, how often you're willing to do resistance exercise of any kind. And again, it doesn't matter if you're using bands or weights or body weight. For instance, if you're doing chin ups, chances are, unless you are very strong, that you're not using weights, you're just using something that you can hold onto. If you're doing push-ups, some of you will be working in that 30 to 80% of your one repetition maximum range. It doesn't necessarily mean that you have to be moving weights in a gym, for instance. So the purpose here is to figure out what muscles you're trying to train. That's an issue that we'll talk about in a moment. And then it does appear that somewhere between five and 15 sets per week is going to be the thing that's going to work for most people. Now this is based on a tremendous amount of work that was done by Andy Galpin and colleagues, Brad Schoenfield and colleagues and others. Mike Roberts, there's a huge group of people out there doing exercise physiology and a small subset of them that are linking them back to real world protocols that don't just pertain to athletes. So that's mainly what I'm focusing on today. And surely there will be exceptions. Now, if you're going to divide the sets across the week, you're not going to do all 10 sets, for instance, for a given muscle group in one session, then of course it's imperative that the muscles recover in between sessions. And we are going to talk about recovery, both at the systemic level, the whole nervous system, and at the local level, the nerve to muscle and local even muscle level. We'll talk about that in about 10 minutes when we talk about recovery. I do want to mention something very important, which is that everything I'm referring to here, it has to do with full range of motion. Okay. And you might ask, well, what about the speeds of movements? This is actually turns out to be a really interesting data set for generating explosiveness and speed. So for sprinters or throwing sports, or for people that want to generate a lot of jumping power, it does appear that learning to move weights as fast as you safely can, especially under moderate to heavy loads. Can increase explosiveness and speed. And most of that effect is from changes in the neurons. It's not from changes in the muscle, it's from changes in the way that the upper motor neurons communicate with the lower motor neurons and generating a pathway, a neural circuit, as we call it, that is very efficient at generating action potentials, which are the electricity within neurons to trigger the muscle. Now, of course, there are events that happen from nerve to muscle, but the takeaway from that enormous literature, frankly, is that if you want to get faster, yes, it can be beneficial to get stronger. But if you want to dedicate resistance training specifically to jumping higher to running faster, to throwing further and these sorts of things that learning to generate force with increasing speed is going to be beneficial. On the flip side of that, for people that want to get stronger, it appears that the slowing down of the weight as things get harder is a key parameter in recruiting those high threshold motor units. So let me phrase that a little bit differently. Think about a set in the gym or think about a set of pushups or a set of pullups. Initially, you can move very fast if you like. If you want to generate hypertrophy, the goal really is not necessarily to move super slow, but to isolate the muscle and therefore not to use momentum rather than lift weights as they say, challenge muscles. If you want to get stronger, you're going to be distributing that effort over more muscles and more of your nervous system. For generating explosiveness and speed, it's very clear that learning to generate forces quickly and to move heavy or moderately heavy loads quickly is going to be beneficial because of the way that you train the motor neurons and of course changes in the muscle. But this could look different for different sports and obviously you want to make safety paramount. If you're injured, you're not going to be able to train at all for sport or for any purpose that is. And so what this would involve is something like 60 to 75% of a one repetition maximum and then in a controlled way moving that as quickly as one can throughout the entire set and certainly not going to failure because as you approach failure, the inability to move the weight with good form, the weight inevitably slows down. In fact, there are a lot of new technologies now that are focused on informing people of how quickly the bar or weight is moving. I saw an advertisement for this the other day. There are things that people can attach to bars that will literally speak to you as you're doing a set and inform you whether or not you're moving four times more slowly per rep than you were at the beginning and trying to hone in on the exact speed of movement. In talking to these experts prior to this episode, it does appear that for sake of hypertrophy as long as you're not moving the muscle so quickly that you start to distribute the effort to lots of other muscles. It doesn't really matter because as the set gets harder, the motor units that you recruit will increase the number of neurons that you recruit and the number of muscle fibers in which these high threshold muscle fibers will increase. It's really only for purposes of hypertrophy that you really need to be concerned about how quickly the weight is slowing down. However, if you're trying to get faster and more explosive and generate more speed and jumping power, throwing power, things of that sort, you never really want to use a weight or get to a portion of the set where you're moving the bar very, very slowly. I'm sure as I say that some of the exercise physiologists and advanced trainers out there will come after me with pitchforks which is fine. I'd love to see the literature that shows that low gear slow movements with very heavy weights can indeed improve explosiveness. That may in fact be the case, but the data that I was able to access was essentially as I described just a moment ago. So as you're probably starting to realize, you need to customize a resistance practice for your particular needs and goals. And I certainly am not the first to suggest that people periodize their training that they do things from anywhere from one month to six months and to see how it goes and to make modifications as they go. Because the nervous system in particular, the neuromuscular system changes very quickly at the beginning of training. In fact, some of the changes that one can see when they first embrace or start resistance training can be very remarkable, but they tend to slow over time. So we've talked about a few principles, the fact that you need to get sufficient volume, you need at least five sets to maintain and you probably need about 10 sets per muscle group in order to improve muscle that moving weights of moderate to moderately heavy weight quickly is going to be best for explosiveness that isolating muscles and really contracting muscles hard something that you can test by just when you're outside the training session, seeing whether or not you can cramp the muscle hard will really will tell you your capacity to improve hypertrophy or to engage. Strength changes in that muscle that your ability to contract a muscle hard is inversely related to the number of sets that you should do in order to isolate and stimulate that muscle. And there are some other things that can enhance the whole process of building nerve to muscle connections, making them more efficient and generating if you like more strength and hypertrophy. One of them I loath to say I was told is in between set contractions. The other name for this is the people in the gym does typically seem to be guys in the gym flexing their muscles in between sets and indeed the research supports the fact that contractions of about 30 seconds in between the actual work sets. They're not going to favor better performance on the work sets if anything they're going to compromise them but those hard contractions in between sets for a variety of reasons related to local muscle metabolism as well as what we talked about before which are stress tension and damage they seem to improve stress tension and damage and the nerve to muscle contraction in ways that facilitate hypertrophy. In other words, you see that person flexing in between sets in the gym provided that they're really isolating that muscle and provided it's one that they ought to be improving not one of these people that always skips leg day type of people these people are highly asymmetric. Although that's up to them that process of flexing in between sets does seem to improve the nerve to muscle connection and enhance hypertrophy and I say I was loath to say it because nowadays with phones it seems like the end of every set includes a selfie and it's sort of like the 11th rep of every set I like to joke it seems like very few people are capable of actually going into the gym and doing a workout without taking a picture themselves which I think is fine if that's your thing. Although I must say that the athletes that I know and even the recreational athletes that I know who seem to get the most out of their training and who also seem to get the most out of other aspects of their life seem to be able to control their phone behavior both in the gym and outside of the gym but that's more of an editorial point there. In an earlier episode I talked about estrogen and testosterone and during that discussion I talked about the use of resistance exercise specifically for increasing testosterone both in men and in women and indeed that is a powerful effect of resistance exercise and indeed it's mediated by the nerve to muscle connections we talked about that in that earlier episode I just want to briefly mention that protocol since it's distinctly different from the other protocols I've talked about today the protocols I've talked about today thus far of explosive movements or of hypertrophy based training provided the training is 60 minutes or less will cause increases in serum testosterone that's been shown over and over again and if the session extends too long past 75 minutes and is of sufficiently high intensity chances are testos are testosterone levels will start to drop and cortisol levels will go up in ways that could be detrimental to recovery and the goals of the training but that's different than training that specifically geared toward increasing testosterone Duncan French who's one of the directors of the UFC performance center when he was a graduate student at University of Connecticut stores did some beautiful work he and his colleagues found the ideal training protocols for stimulating testosterone release which is something that many people want to do for a variety of reasons and that involved doing six sets of ten repetitions even if it requires lightning the weight on one set to the next with about two minutes 120 seconds rest in between sets which if you think about it is pretty short rest and is pretty darn hard work now what's interesting is that there's a very limited threshold for increasing testosterone that protocol of six sets of ten repetitions led to these big increases in serum testosterone but if people did ten sets of ten so just four more repetitions per set then testosterone did not increase in fact you got more of this catabolic cortisol like pathway you get other benefits from the so so called ten sets of ten protocol but not the testosterone increase and maybe even reductions in testosterone now it's important to point out that that six sets of ten was done with big compound movements so things like squats or deadlifts or chin ups or things of that sort and those were done as single sessions not in concert with a bunch of other exercise although if athletes are doing that there's no reason why they couldn't also do other types of training elsewhere in the week I asked Duncan about this and he mentioned that that done twice a week is probably the maximum amount that anyone could do that and still maintain this increase in testosterone it's a very interesting protocol because as the neuroscientist it's amazing to me that six sets of ten repetitions with something causes distinctly excuse me it causes a distinctly different result in terms of hormone output then ten sets of ten of the exact same movement and it speaks to the exquisite way in which nerve to muscle connections dictate the whole physiology of your entire system if there's a theme that I really want to bring forward today is that weight training or resistance training of any kind is really used for either systemic effects right ten percent of training done where you're feeling that burn which means lactate will be present and sending signals to your brain and your heart and your liver that are beneficial or isolating muscles which may also generate a kind of a lactate or which is associated with the burn result but that isolation of muscles distinctly different so systemic versus isolated those are the two general ways in which resistance training can be applied so I just wanted to mention that earlier protocol because it's well supported by the literature if you were to incorporate that protocol you might ask well then can you do any other weight training and you can do that. So let's talk about how you know if you're recovering how you know if a muscle is recovered and how you know if your whole system is recovered because recovery is what dictates whether or not you can come back and do more work of a different kind meaning I know you do leg training one day can you and should you come back and do upper body training the next day and it dictates whether or not you'll see any improvement from session to session at all before I talk about recovery and you can do that. So I just want to make sure I know down the details that I was able to extract from the literature and from my conversation with Dr. Galpin if you're wondering how quickly to perform repetitions for sake of hypertrophy or strength gains anywhere from a half a second per repetition all the way up to eight seconds per repetition it doesn't seem to matter again if you're thinking about explosiveness or building speed or you're specifically using resistance training to build endurance that's a separate matter we talked about that. We talked about explosiveness and speed I'll talk about endurance in a few moments we also talked about in between set contractions so called selfie effect of people flexing a particular muscle isolating a particular muscle between sets just want to mention that would be a terrible thing to do if your goal is performance on sets so moving a particular amount of weight that's actually going to diminish the amount of weight that you can move it's going to enhance muscle growth and it's going to enhance the nerve to muscle isolation. Of that particular pathway so again that flexing between sets is going to favor hypertrophy not performance if you're trying to get stronger you're trying to move more weights you're trying to distribute work and you're trying to do maybe skill training with resistance then flexing between sets is absolutely the wrong thing to do for obvious reasons you're fatiguing the muscle further just remaining still or walking around a little bit has been shown to be beneficial in terms of moving the muscle. In terms of moving some of the lactate out of the muscle as well as just recovering between sets now how long to recover between sets is a question for the testosterone protocol Duncan French and colleagues found that it was about two minutes keeping that really on the clock two minutes not longer for hypertrophy and for strength gains it does seem that resting anywhere from two minutes or even three or four even five or six minutes can be beneficial and if you're interested in expanding the volume of work that you can do in a given section. At high capacity at high intensity with a given weight please see the episode that I did on cold and performance about super charging performance which is based on the work of my colleague Craig Keller in the biology department Stanford which talks about Palmer cooling about how you can cool the core of the body best through the palms using these particular Venus portals that are only present in the in your hands people are now doing this with ice packs or with gel packs there are a number of different ways one can do this I talk all about that in that episode it allows you to do more repetitions and more work at a given weight over time so rather than getting ten repetitions and then eight and then seven and six through proper use of Palmer cooling one can do ten ten ten ten and even add sets that's one way that one can accomplish higher volume work without having to drop the weight considerably so that's where you can hit that really sweet spot if that's your goal of getting strong and generating some hypertrophy because as soon as you have to drop to lower to lighter weights excuse me then you're shifting more towards hypertrophy and endurance and less toward strength in a given muscle so check out that episode the last thing besides between set contractions and whether or not you're distributing work or whether or not you're really trying to isolate muscles is this notion of pre exhausting muscles it's been shown over and over again that for instance if you want to generate force in a given muscle and really isolate that doing the isolation work before a compound movement so this would be you know leg extensions the thing where you sit and you extend your your toes up toward the ceiling leg extensions before squats will allow the squats to target that muscle group more effectively and that makes perfectly good sense based on the hand and size principle and fatiguing motor units it should be obvious why that's the case but of course that's going to be anti performance in terms of how much weight you can lift and maybe even the form that you can maintain when you move to the bigger compound movement so you really have to ask yourself a number of questions how good are you at isolating a given muscle therefore how many sets do you want to do how often are you willing to train therefore how many sets are you going to do in a given session versus how many are you going to distribute across the week are you aiming for performance are you going to distribute that work across the nervous system in musculature are you trying to move weights are you trying to challenge muscles if you're trying to challenge muscles then you really want to focus on things like this pre exhausting the isolation of a muscle before the compound movement your performance on compound movements will absolutely suffer but your ability to isolate that muscle and generate hypertrophy through the accumulation of larger myus and those bigger balloons will benefit and once again if you're trying to get faster then the speed of the movement really matters so how do we know if we've recovered how can we test recovery and this is not just recovery from resistance training this is recovery from running recovery from swimming up until now I've been talking about resistance training more or less in a vacuum I haven't even touched on the fact that many people are running and they're doing resistance training or they're swimming and they're doing resistance training it's not simply the case that if a given muscle is fatigued you can just work other muscles because even if you beautifully isolated a muscle let's say you have incredible abilities to isolate just your quadriceps for instance and you do a workout where you isolate your quadriceps you do your six sets of intense work or maybe use palm or cooling and you're able to do 12 sets of intense work and you're done and that muscle group the next day is certainly not going to be recovered unless you're somebody who's extraordinary at recovery or you're enhancing your recovery through chemical means which we will talk about at the end well you can assess systemic recovery meaning your nervous system and your nervous system's ability to generate force both distributed and isolated through three main tests and fortunately these tests are very simple and two of them are essentially zero cost required no equipment. HRV heart rate variability has made its way finally into the forefront of exercise physiology and even into the popular discussion. I've talked about HRV before how when we exhale our heart rate slows down because of the way that our diaphragm is connected to our heart and to our brain and the way our brain is connected to our heart excuse me when we inhale our heart rate speeds up and that is the basis of heart rate variability heart rate variability is good it means that you're breathing properly and when I say it's good it means you want a lot of heart rate variability you don't want a heart heart rate that is high or low consistently over time. That might come as a bit of a surprise for you endurance athletes who probably are trying to accomplish your endurance work with at a steady cadence and really hit that nice sweet spot where you're breathing rhythmically your heart rate is going rhythmically you're in that steady heart rate and then away from exercise you have a nice low heart rate as they say well nice low heart rate isn't necessarily always so nice turns out the introducing bouts of increasing your heart rate during exercise and even through your waking day through stressful events even is provided their brief is beneficial. A good nerve to heart system benefits from being able to increase heart rate and decrease heart rate heart rate variability is good so you don't want high heart rate you don't want low heart rate all the time but heart rate variability is difficult for a lot of people to measure there are some devices that will allow you to do that various watches and devices there are more devices becoming available all the time hopefully soon some that are integrated with your phone that involve no contact or anything on your body. But those do carry some cost and they are not perfect yet the measures of heart rate variability that one can use while in movement are you know still in the phase I would say of technology development where everyone isn't using them let's leave it at that there are two measures however whether or not you recovered that you can use first thing in the morning when you wake up maybe after five 10 minutes if you like but ideally right when you wake up in order to assess how well recovered you are in there. So you should be able to recover you are in there for whether or not you should train your whole system at all that day the first one is grip strength grip strength the ability to generate force at the level of squeezing the fist or you know squeezing down on something might seem like kind of a trivial way to assess recovery but it's not because it relates to your ability to use your upper motor neurons to control your lower motor neurons and to generate isolated force. So you can use a grip strength when you do that some people will use you know one of these grip tools or there is a costello has this toy that shaped like a donut and it's this hard rubber and I've tried this before you know if I've been working really hard not sleeping very well or I've been training a lot any one or combination of those things my grip suffers I can't actually squeeze that thing down as much as I can costello because he was born with a you know like a 24 inch neck and even though he's never touched a weight somehow he can just clamp down on that thing and it just you know you can just do that. He can turn into a pancake with ease and he likes to chuckle while I struggle with this thing but on a good day I can squeeze this thing so that I eliminate the whole in the donut so to speak you can also take a floor weight and excuse me a floor scale and squeeze the scale and see how much force you can generate. I would do that as a baseline to establish what you can do when you're well rested and then if you do that in the morning you can see whether or not you're able to generate the same amount of force or you could use over the rubber donut or something. This is very subjective. With a scale, you're really trying to assess whether or not you can generate the same amount of force. If you start seeing a 10% or 20% certainly reduction in that, that's concerning. It means that your nervous system as a whole, it's not necessarily fatigued. It's that the pathways from nerve to muscle are still in the process of rewiring themselves in order to generate force. You might think, well, I trained one muscle group one day. Why am I having a hard time doing this for a completely different muscle group? Doesn't make any sense. There's something about the upper motor neuron to lower motor neuron pathway generally that allows you to use something like grip strength as a kind of a thermometer, if you will, of your ability to recover. Look for your ability to generate force in grip when you first wake up. It's not going to be as good as it is at 3pm after a cup of coffee and a couple meals, but the point isn't performance overall. The point is to assess whether or not you're getting better, worse, or the same from day to day. The other one that's really terrific and the Andy Galpin's group is using, and I'm delighted about this because it relates to something that my lab is very excited about as well, is carbon dioxide tolerance. This is a really interesting tool that endurance athletes, strength athletes, I think can all benefit from. In fact, athletes and people of all kinds, even if you're not an athlete, even if you're not exercising at all, there's a good question of whether or not your system as a whole is doing okay or not. We rely on the thermometer. Do we have a fever or not? Do we rely on subjective things? Do I feel good or not? Am I digesting well or not? Those are all subjective. The carbon dioxide tolerance test is objective in that it measures your capacity to engage the so-called parasympathetic arm of your nervous system, which is the calming aspect of your nervous system, and it measures your ability to consciously control a particular skeletal muscle, which is your diaphragm. Here's how you do the carbon dioxide tolerance test. You wake up in the morning. If you have to use the restroom first, do that. Try and stay away from your phone. If you have your phone put on airplane mode, go to the timer or use a hand watch or some other way of measuring time. Stay off social media for just a few seconds. It'll be okay. What you're going to do is you're going to inhale through your nose as deeply as you can. You do this lying down, sitting, whatever. Inhale through your nose and then exhale all the way. That's one. Repeat that four times. Inhale, exhale. Inhale, exhale, inhale, exhale, exhale, four times. Ideally you're inhaling through the nose and you're exhaling through the mouth. That's just the beginning of this carbon dioxide tolerance test. Then you take a fifth inhale as deep as you can through your nose. Fill your lungs as much as you can. If you can try and expand your stomach, go out while you do that. That means that your diaphragm is really engaged. You're inhaling as much as you possibly can. Then hit the timer and your goal is to release that air as slowly as possible through your mouth. It looks like you have a tiny, tiny little straw in your mouth and you're letting it go as slowly as you possibly can. Measure what we call the carbon dioxide blow off time or discard rate. I know you can all sit with lungs empty after you eliminate all that air. But don't lie to yourself. Don't stop the timer when you've been sitting with your lungs empty for a while. Stop the timer when you are finally no longer able to exhale any more air. So you do inhale, exhale, inhale, exhale, inhale, exhale, inhale, exhale, slowly. I just said it quickly for a sake of time. Then you do this fifth big inhale through your mouth and then and I'm not going to do it for the full duration. And then you're measuring that time. Your carbon dioxide discard rate will be somewhere between one second and presumably two minutes. Two minutes would be a heroic carbon dioxide discard time. 30 seconds would be more typical, 20 seconds would be fast. If your carbon dioxide discard time is 20 or 25 seconds or less, you are not necessarily recovered from your previous days activities. There's ways to push through this but hold on to that thought for a moment. If your carbon dioxide discard time is somewhere between about 30 seconds and 60 seconds, you are in what we would call kind of the green zone where you are in a position to do more physical work. And if your carbon dioxide discard time is somewhere between 65 and 120 seconds, well then you have almost certainly recovered your nervous system. I'm not talking about the individual muscles but your nervous system is prepared to do more work. And Andy's lab has great data on this as it relates to exercise physiology. I think that story should be out in the not too distant future. My lab has been using carbon dioxide discard time to look at anxiety and recovery from bouts of anxiety. So two totally independent projects but using the same measure. So you've got HRV which requires some technology usually. You've got grip strength which you can assess subjectively or you can use a floor scale. And now you have carbon dioxide tolerance. You want to do this in the morning when you wake up. And keep track, just write down in a little book or maybe just keep track in your mind of your carbon dioxide discard time. If you find that your discard times are dropping even if they're in the 42nd range or 52nd range. But normally you can do 75 seconds or 120 seconds. If they're starting to drop by anywhere from 15 to 20%. You're veering in the direction of not recovering. And I'm really keen on this tool because everybody has different recovery abilities. And people are eating really well and sleeping really well. Some people have minimal stress or can buffer stress really well. Other people, you know, they dissolve into a puddle of tears if they read one, you know, text message that's troubling or whatever. You know, and I realize and I say that was sympathy. I realize people have varying levels of stress and demand in their life. It's just impossible to prescribe an entire protocol that says, okay, yes, you should train today. And this is exactly what you should do. No, you shouldn't. You should get an oxide discard rate because A, it's valuable. It's informative. B, it's zero cost and C, it's something you can track objectively over time. And that's really the key. And I just should I'd be remiss if I didn't say that what carbon dioxide discard rate is tapping into is your ability to mechanically control your diaphragm. Certainly, that's one aspect of it. But that relates in a very direct way to your ability to put the break on your stress system to engage the so-called parasympathetic or calming arm of your autonomic nervous system. And another thing that Andy Galbin's group is testing is at the offset of training after your run, after your weight training session, maybe even after your plyometrics session, we didn't really talk about jumping and throwing and that sort of thing. Maybe we'll talk about it in a future episode. And they and other groups, including some elite athletes and other groups that are very interested in physical performance, are using a tool where they deliberately disengage for five minutes at the end of training. They deliberately engage this calming or parasympathetic arm of the nervous system. And you can do that through any number of different tools. I'm a big fan of respiration tools because they're always available to you. Your breathing is always there. I talk about some of these tools in previous episodes, but you could use things like non-sleep deep rest and SDR at the end of a training session. You could do 10 physiological size, double inhales through the nose, followed by long exhales, that will definitely engage the parasympathetic nervous system at the end of training. So rather than finish your training session and then just hop onto your phone, serious athletes and people who are serious about recovery, initiate that recovery at the very end of their training and they start to kickstart that recovery process rather. And they measure CO2 tolerance in the morning. So there are several groups that are doing that. In fact, I know several groups because I'm working with them that are using physiological size between sets in order to recover their nervous system and maintain nerve to muscle contractability, maintain focus throughout their training session, enhance their focus by doing a few physiological size, so double inhale, exhale in between sets. So they're getting very focused and very intense about their strength work or explosiveness work or muscle isolation work during their sets. And then in between sets, they're deliberately disengaging the nervous system and then they're re-engaging it again. So I just wanted to emphasize that. So recovery is a complex process. It's got a lot of things, but the CO2 tolerance set should be a valuable tool. Now another tool for recovery that people are very excited about is the use of cold and the ice bath. And this is important if you are somebody who uses cold through cold shower or ice bath or jumping in a lake or a river, whatever it is that you use to generate cold as a recovery tool, you should be aware that there are data starting to emerge that if your goal is recovery or strength improvements, using cold within the four hours following a workout. I'm not saying about polymer cooling. I'm talking about whole body cooling or cooling from the neck down. Yes, it will reduce inflammation. Yes, it will reduce the amount of delayed onset muscle soreness. One read out of how intense or damaging a given workout was, not the only read out. But it does seem to interfere with some of the things like mTOR pathways, the mammalian target of rapamycin pathway and other pathways related to inflammation that promote muscle repair. Remember, and muscle growth. Remember, stress, tension and damage are the stimulus for nerve to muscle connections to change and for muscles to get bigger, stronger and better. And so if you're getting into the ice bath after training or taking a really cold shower after doing resistance training, you are likely short circuiting the improvements that you're trying to create. Now athletes who are trying to recover quickly so that they can get back into more training sessions or let's say you're somebody who doesn't really want to gain much strength or hypertrophy and you're mainly focused on endurance and you want to do more endurance work and you've been weight training, well then exposing yourself to cold can be beneficial. But you're not going to get as great of benefits from the resistance training. In other words, cold after resistance training seems to short circuit some of the benefits of that resistance training. There are some other things that can short circuit the benefits of resistance training as well. One of those is anti-histamines. Some interesting data were published recently, I believe it was in scientific reports, yes, that showed that anti-histamines can prevent some of the benefits of cardiovascular exercise of endurance type work, running, swimming, fairly long duration or even sprint type work as well as inhibit some of the processes associated with resistance training. Remember resistance training or endurance training, that's a stimulus for stress and the adaptation to that stress is how you get better that you can run further faster, lift more weight, hypertrophy, the muscle, etc. So anti-histamines can be a problem. Obviously, don't compromise your ability to breathe completely, but anti-histamines generally work by blocking what are called mast cells. M-A-S-T, mast cells are really interesting cells that we'll talk about in our month on neuroimmune function. They travel in the bloodstream and there are these little packets that burst open at sites of inflammation. Muscle damage and inflammation is a signal that something needs to change. And so, taking into histamines it appears can disrupt some of that inflammatory process. So you actually want inflammation during and immediately after a workout, then you want to bring inflammation down later. And I'll mention how to do that. The other thing are non steroid anti-inflammatory drugs. You know their trade names. These are pain killers that many people take. Those as I've mentioned in a previous episode can interfere with the benefits of endurance training and the benefits of resistance training. In addition to that, they block pain signals and pain is a very good signal that you might be doing something wrong. And so while nobody likes to be in pain, I suppose there are probably a few people out there like to be in pain, but that's a different story. But nobody likes to be in pain. The non steroid anti-inflammatories, the NSADS, as they're called, in the end of histamine, seem to prevent a lot of the gains, the improvements in endurance, strength, and size that people are specifically using exercise for. So be cautious about your use of non steroid anti-inflammatory drugs, especially within the four hours preceding or the four hours following exercise. So I hope you're starting to get the picture. In order to change the nerve to muscle connectivity in ways that will better serve you, you need a stressor during the actual training, which particular stressor depends on your training goals. But that stressor is almost always going to be associated with inflammation. And then after the training, you want to try and get into a state of reduced inflammation. And that's why you would do some sort of protocol, non-sleep deep rest, which we will link to in our caption, or perhaps you would use the hypnosis app that we've talked about before, reverie-r-e-v-e-r-i.com. There's a great app for accessing deep rest states or the physiological side to try and get the system, your system, to calm down after training. There are also tools that one can use to reduce inflammation at a kind of foundational level away from training. And these are tools that I've talked about many times before, but I'll just restate them again. The kind of golden three, according to Andy Galpin, and the ones that he recommends are sufficient omega-3s. Again, that can be accomplished through diet, through whole food intake, or through supplementation or both. So, in general, getting above a thousand milligrams of EPA per day to keep inflammation low or relatively low. Vitamin D. And in some cases, magnesium mallate. Vitamin MALLATE seems to be particularly effective in offsetting delayed onset muscle soreness. Soreness itself is not required for improvements in strength, improvements in explosiveness, improvements in hypertrophy. That's a myth. Now, if you do experience delayed onset muscle soreness, chances are you stressed that particular muscle pretty well, or even maybe too well, maybe you stressed it too much, and you need longer recovery. There's a total debate out there about whether or not you should train again when a muscle is still sore. I think the general takeaway is no. That means it's not recovered. And there are things, of course, like massage, like facial release, and things of that sort, sauna, cold, that can perhaps accelerate the movement from soreness to not sore. But in general, the omega-3 vitamin D and magnesium mallate, excuse me, trio seem to be an effective way to reduce inflammation at a systemic level. But remember, you want inflammation provided you're not damaging the muscle so much that you're injured during the training session because that's the stimulus for change in those muscles. I want to talk about a few other things that support the process of nerve to muscle communication, and touch on some of the things that a lot of people are doing to try and quote-unquote enhance their workouts and evaluate whether or not those are, in fact, enhancing workouts or not, because weight training, unlike a lot of other forms of exercise, has a unique aspect to it, which is this feature that I guess some people call it, the pump, which is the fact that blood goes into the muscle when you train. It's the only kind of training where you actually get a window into what the result might actually look like before you actually accomplish that result. So if you think about when you go out for a hard run, and let's say you, you go out for a two mile run, let's say your goal is to break, you want to do a sub-ten two mile. Actually, when I went to university, I was running cross country my senior year of high school, and I wanted to walk on for the cross country team. So I went out there and turned out you had to do a sub-ten two mile. I think the best mile I ever ran in high school was a 457, which isn't terrible. I can't do that now. It's not even close to what high school athletes, the best high school athletes can do now. But that would have meant doing it back to back. So a sub-ten-minute two mile didn't even come close until Costello, the story of the other day, and he just kind of laughed at me. He was like, why would you even want to run two miles? Because Costello is built almost exclusively of these type two fast twitch muscles they're designed for moving objects. He's incredibly strong. He has been since he was a puppy. I mean, that dog could probably drag a tractor if he wanted to, but he can't really go far. Whereas a gray hound or a whip it or some of these other site hounds or sent hounds can go, go, go. They have a higher percentage of the so-called slow twitch muscle fibers. They are much better at endurance. So a sub-ten two mile would have been very, very challenging. No chance I could have done that. I don't think even with a lot of training. But let's say that you want to improve your performance in a given type of exercise. Let's talk about some of the things that seem to work across the board to improve strength in improve hypertrophy and improve nerve to muscle communication and performance. The first thing that's absolutely key for nerve to muscle communication and physical performance of any kind might not sound that exciting to you, but it is very exciting. And that's salt. Nerves, nerve cells, neurons communicate with each other and communicate with muscle by electricity. But that electricity is generated by particular ions moving into and out of the neuron. And the rushing in of a particular ion, sodium, salt is what allows nerve cells to fire. If you don't have enough salt in your system, your neurons and your brain and your nerve to muscle communication will be terrible. If you have sufficient salt, it will be excellent. How much salt will depend on how much water you're drinking, how much caffeine you're drinking and how much food you're ingesting. And whether or not you're taking any diuretics, how hot it is, et cetera, how much you're sweating. So you want to make sure that you have enough salt, potassium, and magnesium in your system if you want to perform well. I realize salt isn't a very glamorous performance tool, but it is vital. It is absolutely vital. And the endurance athletes and the people that train in high heat can speak to the fact that when your electrolytes are low, your brain doesn't function, your body doesn't function nearly as well. It's even for mental work, for studying and for writing and for doing math and coding, doing analytic work of any kind, even a hard conversation that's important to you. Having sufficient electrolytes is really going to help and being low on electrolytes won't help. And just drinking water won't help because you need electrolytes. The other thing that's been shown over and over again, numerous well-controlled studies to improve muscle performance is creatine. Even on there was a lot of controversy about creatine, but there are many studies. If you want, you can go to this website that everyone now knows I love, which is this free website, examine.com, that there are no fewer than 18 studies there. 66 studies. So 18 studies supporting that muscle-creating content can be increased by ingesting creatine. How much creatine? Well, I asked the experts and they tell me that for somebody who's about 180 pounds, if grams a day should be sufficient or so, heavier than 180, so if you get like if you're 220 pound or 233 pound person, 10 to 15 grams of creatine, people lighter than 180 pounds, maybe three to five grams of protein, excuse me, creatine or even one to three grams. Creatine is a fuel source for early, early in bouts of activity, for high intensity activity. It is also a fuel source for neurons in the brain and it can have some cognitive enhancing effects. 18 is a very interesting molecule early on when it was released as a supplement. It was thought that you had to load it in higher dosages for a few days and then maintain it at lower dosages. So you take 20 or 30 grams a day then back off to five or 10. It doesn't seem to be the case that you can get all the benefits from taking the dosages at the low level. I just mentioned a few moments ago as they relate to body weight throughout. So salt and electrolytes, absolutely key. You need those pressing. Well hydrated. Creatine seems to have a performance enhancing effect. There are 66 studies, 66, showing that power output is greatly increased anywhere from 12 to 20 percent. And this is sprinting and running and jumping as well as weight lifting by creatine. The ability to hydrate your body is improved by creatine because of the way that it brings more water into cells of various kinds. As an indirect effect, it can help increase lean mass because of the way that it brings more water into muscle and probably also because of the way that if you get stronger, you can generate more force and generate more hypertrophy. It reduces fatigue. Seven studies have shown that reduces fatigue. There are even some interesting effects on improving cognition after traumatic brain injury. Although that's a serious medical condition in situations you absolutely should talk to a board certified physician before adding anything or taking anything out of your current regimen. There are a few other effects that are interesting and notable, but the big ones are the ones that I referred to before about increased power output, etc. And I just want to emphasize that creatine can increase this hormone that we talked about in the testosterone episode, dihydrotestosterone, which is testosterone converted by 5 alpha reductase into dihydrotestosterone. It's the more dominant androgen in humans. To increase in strength and libido and so forth, it also can increase male pattern baldness. Some people, not everybody, experience some hair loss with creatine. Other people don't. Some people experience accelerated beard growth because basically, D.H. she has the opposite effect on hair follicles on the face as it does on the scalp. Some people don't. Women who ingest creatine, there are essentially no data showing that it increases hair loss or facial hair growth. But of course, everyone is different, so you can go to exam.com, you can explore those studies. Creatine definitely a powerful performance enhancing molecule. The other one, one that personally I've never tried, but that seems to have very strong and well-supported effects, is beta-alene. Now beta-alene is interesting because when you hear about weight training, you think about heavy dead lifts and bench presses, all that kind of stuff that people are doing. Beta-alene seems to support exercise that is of slightly longer duration. So a mix of anaerobic and aerobic type movements. These are physical performance in the 60 to 240 second range. So you can use your mind and kind of figure out things that limit you to 8 to 15 repetitions. Cardiovascular exercise of the sort like rowing or sprinting, so interval work. It seems to help with that kind of work. We're not talking about long runs, we're not talking about heavy dead lifts. The standard dose is somewhere between two and five grams. Again, as always, check with a doctor. Make sure these things are safe for you. I'm not responsible for your health. You are. I don't say that just to protect me. I'd say that also to protect you. But it really seems to improve muscular endurance, improve anaerobic running capacity, reduce fatigue. There are even some interesting effects on reduction of body fat and improvements in lean mass. So creatine beta alanine electrolytes, these are kind of the core three things that seem to improve performance and are well supported by the scientific literature. And in the earlier episode on supercharging performance, we talked about palm or cooling. That's certainly a performance enhancing tool. It's nothing you ingest. You're cooling your palms in a very specific way. That's very powerful. Now, what about for longer duration bouts of exercise? We've mainly been focusing on resistance training. But what about for long runs, long swims, these kinds of things? Well, it does seem that beat juice and ingesting things like arginine and citrilline can improve performance for those long bouts of exercise. That's mainly going to be due to effects of those compounds on vasodilation. It's going to open up the vasculature and allow more blood flow. Do note that things like citrilline and arginine can have some side effects, if you will. They can increase the likelihood of having herpes cold sore outbreaks on the mouth. Arginine is in the pathway by which I don't know if people know this, but the herpes virus lives on neurons of the trigeminal nerve that innervate the lips and the eyes and the mucus membranes of the face. So this is the herpes type one simplex virus that virus lives on those neurons and then periodically inflames those neurons. And that's what leads to the cold sore. It seems like arginine and citrilline can lead to increases in cold sores and canker sores and outbreaks of those kinds. So you want to be aware of that. That's not everybody, but not everybody is carrying HSV1. Just be aware that I think it's now 80 or 90 percent of people by time they are 12 years old. They've contracted HSV1. It's very contagious and typically we have one outbreak and then only under conditions of stress or heightened arginine or citrilline ingestion will have them later. Again, this is not necessarily an STI. This is an infection that is passed very easily from mucus membranes just in terms of touching objects and things of that sort. Very common in the general population. Any discussion about muscle and muscle performance would not be adequate if we didn't mention something about nutrition, but rather than have a whole discussion about nutrition because there's lots of information about that online, for instance, if you want to gain muscle that you need to have a caloric surplus of about 10 to 15 percent. You could have a caloric surplus of more if you want to avoid gaining weight than you would not create a caloric surplus, etc. You can find all that information online. That's not what this podcast is really about. We had a month where we talked a lot about hormones and food and moods. We talked about foods, but more as they relate to the nervous system. When it comes to supporting muscles, supporting the synthesis of larger, what I call myosin balloons, it does seem that ingesting 700 to 3000 milligrams of the essential amino acid, loosing, with each meal is important. Now that does not necessarily mean from supplements. In fact, most people recommend that you get your protein, you get your amino acids, including your essential amino acids, and you're loosing from whole foods. High quality proteins are high density proteins. What do you mean by that? Well, it is true that a lot of sources of protein are found in things like beans and nuts and things like that, that all the essential amino acids can be found there. But per-unit calorie, if it's in your practice, if it's in your ethics to ingest animal proteins, it's true that, for instance, 200 calories of steak or chicken or fish or eggs will have a higher density of essential amino acids than the equivalent amount of calories from nuts or plants. That's just simply the way it works. So I'm not, for the vegans and vegetarians, I'm certainly not saying there's no way that you can support muscle growth. You absolutely can. Some of them might want to supplement loosing, but this 700 to 3000 milligrams of loosing per meal is one of the best ways that's been shown to support the synthesis of more myosin if your goal is hypertrophy, and it's also the way that you would support muscle repair if your goal is strength. So that's specifically geared towards muscle hypertrophy and strength. And I encourage you to think about this protein density issue and whether or not you ingest animal proteins or you don't to think about whether or not you're getting sufficient essential amino acids, especially loosing. Now many people have addressed the question of whether or not you need to eat six or seven times a day. It turns out that you don't. That's kind of the old school thinking that you need to eat very frequently. I think for certain athletes who are very active for drug assisted, meaning people that are enhancing their testosterone levels to super physiological levels where they are experiencing very heightened levels of protein synthesis and they can utilize all that that might make sense. Again, I'm not supporting the use of those performance enhancing drugs, but there are people doing that and that's one of the reasons why they eat so frequently and so much protein for typical people who are not doing that. I imagine most of you are not. Then it does appear that you need to eat, but you don't need to eat six or seven times a day. It does seem like not eating once a day is also important. So somewhere between one meal a day and six meals a day lies the more reasonable two or three or maybe four times a day. I think that a whole discussion about this is warranted and we'll have this discussion with Dr. Galpin in a future time of how whether or not eating protein more frequently can enhance this mysinsynthesis. But I think the simple takeaway from the literature that I was able to extract and from my discussion was with him is eating two to four times a day, making sure you're getting sufficient amino acids in a way that's compatible with your ethics and with your nutritional regimen is going to support muscle repair, muscle growth, strength improvements, etc. Just fine. There's one more thing that I'd like to cover, which is the relationship between particular kinds of exercise and our ability to think and perform cognitive functions. We all hear that exercise is so vital for our brain that it supports our brain health and our body health and indeed that's true provided it's done correctly. However, many of us are familiar with the experience of going for a run or going for a swim or working out hard in the gym and then not being able to use our brain to be essentially useless for cognitive functions for the rest of the day. I discuss this with Dr. Galpin this morning and I learned something very interesting, which is that hard bouts of exercise of the sort where you're training near failure or you're generating focused muscular contractions for obsession that lasts anywhere from 30, 45 minutes, maybe 60 minutes or a long run where you're engaging in some interval training during that run. After exercise, there's a reduction in oxygenation of the brain. There's actually a quite significant dip in the amount of oxygen that your neurons are getting and therefore your ability to think. It's important that you control the intensity and the duration of your training sessions so that you're still able to do well in life and lean in to life the way you need to because I'm guessing most of you are not in a position to just prioritize your physical training. You also need to use your minds. I'm certainly familiar with wanting to get exercise but also the requirement of needing to perform cognitive work throughout the day. It also turns out that you can leverage something interesting about exercise and nerve to muscle work in ways that can benefit cognitive function and focus. It has to do with the way that your body and your nervous system predict bouts of intense focused effort. Let's say you're doing resistance training two or three times a week, maybe even four times a week and you're doing it consistently at a given time. There are clocks, literally biological clocks within the liver and within the brain that learn to predict that focus and that intense work. If you are trying to get intense cognitive work done, you might try scheduling that cognitive work on the days when you don't do physical training at the same time when you normally would do that intense focused physical training because the systems of the body that generate acetycoline release and other nomodulators, the systems of the body and brain that generate focused effort. Those are on this sort of clock mechanism in a way that you likely will find that after just a week of training at regular times, you will be able to focus readily on other things when you're not training provided you do it during the period of time of day when you normally would train. This is kind of an indirect positive effect. You're harnessing the focus and the expectation of focus in your nervous system for that particular time of day. Of course, we'd be remiss if we didn't talk about time of day for training. It's out that whether or not you do, whether or not you train in the morning or in the afternoon, doesn't really seem to matter for sake of things like hypertrophy and strength, etc. Everyone seems to have a time of day that they prefer to train. I've said before in their reasons based on body temperature rhythms and cortisol release that training 30 minutes, three hours or 11 hours after your normal waking time can be very beneficial and can provide a sort of predictability or regularity to when your body will be ready to train and best apt to train well. There is some evidence that training in the afternoon is better for performance, whereas training for body composition changes and strength changes, etc. Doesn't really matter when you train. You also want to make it compatible with sleep, compatible with work. That really gets down into the weeds of optimization. I think it's interesting to note that if you're going to train at a regular time, you can take the days when you don't train and use that to enhance your cognitive focus for things that have nothing to do with exercise. This might be writing or reading or music or math, etc. Typically, I restrict these podcast episodes to about 90 minutes, so-called all-tradian cycle for learning. Today was a bit longer and I admit that I tried to pack a lot into this. It is the last episode in this month on physical performance. I figured in this case, more is better, especially since everything is timestamped for you. You certainly don't have to watch it all at once. You can come back to it over and over again into the precise locations in the episode that you like in order to take notes or extract the information that you need. I'd like to point you to Dr. Andy Galpins' page. I highly recommend looking into the work that he's doing if you want more details. He's very, very skilled, excellent communicator. He's superb at what he does. He's a professor. He works with athletes. He works with typical folks in the exercise and muscle physiology world. Brad Shonefield's work. I also have a lot of respect for him. I've never met him. I don't know him. There's no paid endorsement here. They're not sponsors related to the podcast in any way. I just think the work is of very high quality and they are both on the academic side and the practical side. And of course, there are other people out there doing fabulous work in this area as well. If you like this podcast and you're benefiting from the information that you're learning and you want to support us, the simplest and most straightforward way to do that is a zero cost way, which is to subscribe to, excuse me, subscribe to the podcast on YouTube. Click the subscribe button and to subscribe on Apple and Spotify as well. That really helps us. It helps us get the message about the podcast out more broadly generally and it ensures that you don't miss any episodes. We release episodes every Monday, but starting soon and from time to time, we release shorter episodes in between. So you're sure to hear about those episodes. In addition, check out the sponsors that we mentioned at the beginning of the podcast. If you like and if you're able to, supporting us through those sponsors is a terrific way to support our production staff and the podcast generally. A zero cost way to support the podcast is to tell your friends, tell your neighbors, tell anyone that you think might benefit from the information. The way this podcast is set up, the information is batched into four or five episodes, all centered around a given theme or topic, like hormones, like sleep. So the episodes on sleep, for instance, that were way back in January, or what seems like way back, are still every bit as relevant today as they were back in January for somebody that has challenges with sleep and wants to understand sleep and get better at sleep or wants to understand their dreams or how to use sleep and dreaming to leverage neuroplasticity and learning. So if you pass information along about the podcast, that's great. We also have a Patreon. You can go to patreon.com slash Andrew Huberman. You can support the podcast at any level that you like. And as always, please put your questions about the podcast episodes and suggestions for future episodes in the comment section. I really do read through all those comments. It takes me some time, but I do read through those. I reply to as many of them as I can, but I do read them and they're a great way for us to get feedback. On Apple, you can give us a five star review if you think we deserve that. And if you want to do all these things, you're welcome to. If you want to do just one of them, we understand and if you do none of them, we still appreciate that you come here to digest the information about science and science related tools. In today's episode, I mentioned various supplements, various compounds that if you deem it right and safe for you can benefit athletic performance and muscle physiology, et cetera. We've partnered with Thorne THORne, because Thorne supplements, we believe, are of the highest possible stringency and quality. What you see on the bottle is what's in the bottle and the quality of ingredients that they include are excellent. So much so that they partner with the Mayo Clinic and all the major sports teams. If you go to Thorne THORne.com slash the letter U slash Huberman, you can see all the supplements that I take and you can get 20% off any of those supplements as well as 20% off any of the other supplements that Thorne sells. So if you go to Thorne.com slash the letter U slash Huberman, any of those supplements listed there and then if you navigate through their site and you find something else that you like, we'll be 20% off at checkout. Last but not least, I want to thank you for your time and attention today and as always, thank you for your interest in science.