Overview of the Nervous System

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00:59 Welcome everybody to another episode of Dr. Matt and Dr. Mike's Medical Podcast. This is our regular long form podcast where we go through in relative detail something fun and interesting about the human body. Today we're talking about an overview of the nervous system. So we're going to jump straight into it. But before we do jump straight into it, I want every listener to go either to our YouTube channel and watch this as a video because what you're seeing the video is on the wall behind us. Not only do we have our silver YouTube button. Is that in frame? Button. It is in frame. Okay. The silver YouTube button and plaque that says congratulations Dr. Matt and Dr. Mike for hitting 100,000 subscribers on your YouTube channel. But we have a listener made wooden YouTube button slash plaque which congratulates us on reaching our 500,000th subscriber on our YouTube channel. Thank you, Callum Richardson, you legend from down in Tassie and his brother Tyler who actually is part of the band Luca Brasi. If you have not listened to them, I suggest you go on iTunes and have a listen or Spotify. They are awesome. I've listened to them for years before I even knew Callum. So I think that this is awesome. Thank you both. Thank you so much. It is the best. You can, if you like, contact us. You can do that through email, which is gubiosciences.com or our website, which is drmaththom.com.au. Or you can follow me on all the socials. I just joined threads, which is Zuckerberg's way of hitting back at Elon saying, Hey buddy, I'm not going to do that in Twitter, too. I'm not going to be hitting each other aggressively. I think there is a plan. I don't know if it'll go ahead where Zucks and Musk will battle it out in the Colosseum, the literal Roman Colosseum to death. I think some people would hope so. Look, this is such a weird thing. Did you know Elon Musk is a big dude? Like his over six foot probably weighs about 90 odd kilos and Zuckerberg is like me. He's not a big dude. Short. Well, I was going to say muscular, attractive, but yes, short and but fit. So it'd be very interesting because I don't know how fit Elon Musk is, but I know the Zucks is fit. He did Murph. Have you finished Murph? Have you heard of Murph? No. Murph's a crossfit workout, which is usually done on Memorial Day to recognize those soldiers who have died in combat. And Murph is the name of one of the soldiers. And the workout is from memory. Have you done it? Yeah, I've done a number of times, but I always forget the reps. It's a hundred pull ups, 200 push ups, 300 air squats, and I think something like a five mile run.

04:13 Dr Matt

 In a day or in one go? In one go.

04:17 Okay. But you also wear a 10 kilogram weighted vest. Wow. Or a 20 pound odd weighted vest. And it takes about a bit under an hour, about an hour to do. Wow. Yeah. So Zucks did that and I think he got under an hour, which means fit. So I'll be interested. How many miles? Five miles? I think so in total because there is a run at the start and a run at the end. So you do a run, then you do the 100, 200, 300, then you do the run at the end. That's impressive. Yeah, it's a good workout. It does. It takes at least 45 minutes to do.

04:50 Dr Matt

 I couldn't do the pull up part. I'm terrible at pull ups. I don't think you could do any of the part. No, I reckon the rest I could. With the vest? Yep. Yeah, okay. Five miles is a lot though.

05:00 How long is that in kilometers? It's what? Two point, sorry, one point, no, two point two. Seven Ks? It's about two point two, is that right? One point six. One point six. No, I'm thinking pounds to kilos. One point six. So it'd be around about, yeah. Eight Ks. About eight Ks. Wow, even that? I could be wrong about the details of the the Murph workout, but it's a big workout. Here it is. The Murph workout is, if you want the specifics, it's the run I overestimated. It's a one mile run, 100 pull ups, 200 push ups, 300 squats, then another one mile run and you do this in a 20 pound vest, so a bit under 10 kilo vest. So two miles runs in total? Yes. If you want, listeners, listener, if you want video footage of Matt and I doing this for the podcast and for the YouTube channel, we'll do it. Won't you, Matt? Yeah, yeah. I haven't got a vest. I've got one. I've got two actually, so there you go. Yeah, but it won't fit me. No, that's one size fits big. Not your best size. No, it even says fits redheads. All right, let's jump into it. Like I said, if you don't want to contact us, you can contact us on all those different channels, including social media. I am on threads, like I said, and it's just at Dr. Mike Todorovitch, D-R-M-I-K-E-T-O-D-O-R-O-V-I-C. That's my name. Come say hi. Let's have a chat. Today we're talking about an overview of the nervous system and as we all know… We haven't done this before. No, so we have done aspects of the nervous system. We've done the brain and we've done action potentials and greater potentials and we've done cranial nerves and we've done the autonomic nervous system, but we haven't done it where we've sort of brewing it all together. So obviously we're not going to be going into so much detail that it's going to be a five, six, seven hour podcast. Which it would be, yeah. We could do. I mean, you and I can talk for that long. No, we're not doing it. Keep going. Okay, sorry. But we are going to try and frame it in a way that makes sense as opposed to regurgitating the textbook. We really want to build a nice picture and story as to how relevant are all of these structures and functions. And we're going to begin by me reading a story, a poem, an event, a metaphor, euphemism, all of the above. Okay, here we go. Preparing yourself for the challenges ahead. Your pupils are dilated. Your breathing is labored. You can feel your heart trying to escape from every beat from your chest. As the adrenaline surges through your body, you are now in a heightened state of readiness. Scanning the field, you're capturing every detail. The grass bending under the weight of the cool breeze, the resounding chorus of the crowd echoing across the stadium, the smell of sweat and excitement fueling the symphony of players conducted by the dance of the ball. The red leather catches your eye against the blue background of the sky. Your focus has narrowed. The crowd disappears. The breeze falls away. Time has slowed down as all that now exists is the ball. Your body is primed for the chase. You reflexively sprint towards the falling object. Without thought, you're analyzing the trajectory, the spin, the speed. In that pivotal moment, you extend your arms and your fingers, eagerly anticipating its arrival. The instant the ball touches your fingertips, your mind explodes with sensory input. The texture of the ball, its size, its weight in your hands. You feel a surge of exhilaration and accomplishment. And without hesitation, you surge forward as your hands, arms, legs and feet calibrate and move in perfect unison to kick the ball. With unparalleled accuracy, you deliver the ball between the uprights. In an instant, the sea of people drifts back into focus. You hear the blazing roar of the crowd. You feel the cool breeze across your face, the solid ground beneath your feet, your teammates running toward you and the smell of victory. So. Lovely. Thank you. I wrote that.

09:16 Dr Matt

 Did you? Yep.

09:17 Dr Mike

 With the help of AI? Nope. Not for a second. Wow. Okay, maybe for 10 seconds. That's impressive.

09:22 Dr Matt

 Okay, what was it?

09:25 Dr Mike

 What does all that mean? No, like, was it a sport? Oh, okay. So yeah, so for our dear international listener, this is what I was thinking about Australian rules football. Right. Which probably isn't a great sport to use as an analogy considering most people around the world don't know what that is. But basically, it's a combination between rugby, soccer, Gaelic football, probably a combination of all those. Yeah, I think so. Basically, you've got a red leather ball that you kick and run with and bounce. And the goal is to kick it between. You've got ultimately four posts sticking out of the ground, but you want to, you want to kick the ball between the two middle upright posts. For greater points.

10:12 Dr Matt

 For larger. All right. So you painted this picture of a story of a story to illustrate what the body is capable of. Yeah. Neurologically. Yeah. So you had things there like you spoke about the pupil, your breathing rate, your heart rate pupils. Yeah. So that is in reference to the autonomic functions of the body. Yeah. Yeah. Yeah. You had vision, sound, smell. That's the special sensory. Okay. You had, well, wait, it's back about vision, but the vision being processed to the minute detail. So parts of the brain that is about integrating sensor or visual sensory information to make sense of then you had highly coordinated movement. So that would be something that's hot in the higher functioning of your prefrontal cortex. The cerebellum, the basal ganglia or basal nuclei. Yeah. And then you had had other sensory information being proprioception, tactile, mechanical thing, and then, you know, how the body and the brain speak to one another. So this would be spinal cord, brain, spinal nerves all put together. So that story. Plus reward pathways. Right. Right. So that story was well done an analogy analogy to try to demonstrate how the nervous system although vast and complicated all works together in different ways. Is that right?

11:43 Dr Mike

 Yeah. Yeah. I think obviously it doesn't capture it all, but the aim was to try and give everyday relevance to some of the things we probably take for granted that are due to the nervous system. And we probably know, but we probably don't understand the how or why and the, you know, the way that the gears or cogs of the nervous system interlock in order to create, you know, that the seamless clockwork functioning of the nervous system.

12:14 Dr Matt

 Yeah. So it was a good story. All right. Here we go. Congratulations. Okay. But, but, but there was some missing aspects. Okay. Here we go. So it's hard ladies and gentlemen, it's hard for me to comment because AFL I wouldn't say it's my first choice in winter sports. I didn't grow up in Victoria or South Australia or Western Australia. Yeah. So in New South Wales, Queensland, it's rugby. But anyway, I'll go with the story. Okay. I might mind you Brisbane Lions is pretty good. Anyway, so a couple of things that you obviously missed. All right. So being an AFL game, there would have been a fight in the crowd. Oh fair point. So that would have been something to do with the aggression part of your brain, the amygdala. Right. Good point. Yeah. After the game. So obviously winning the game celebrating with getting drunk. Oh yes. So alcohol and how the effect of alcohol has on the brain.

13:15 Dr Mike

 Also fair. Yes.

13:17 Dr Matt

 And possibly you could look at the recovery. Oh, so ice baths. Yes. So temperature. Electrolytes. Yeah.

13:25 Dr Mike

 So, but you did a fair, fair job. Also didn't talk about, you did talk about fights and also getting a good hard knock of the ball.

13:33 Dr Matt

 Yeah, I was going to talk about ACL injury. So one of the teammates got stretchered off with a ruptured ACL. So that would have been. Out of all Australian sports, this is a bit of a digression. Which sport do you think has the highest injury prevalence for ACLs? I was going to guess it'd be probably something like netball or squash.

13:56 Dr Mike

 It's netball and then it's AFL. Oh really? Yeah. Anyway, digression. Yeah. But that's okay. Two sports that probably people outside of Australia don't really play.

14:05 Dr Matt

 Is netball international? Outside of Australia. It's played in the Olympics.

14:10 Dr Mike

 Okay. Is it? Yeah. All right. There you go. There you go. It's not really a sport that. Or at least the Commonwealth Games. Yeah, it's probably just that because I can only think of Commonwealth countries that tend to play it. Yeah. It's usually New Zealand, Australia, possibly England. If you're a non-Commonwealth listener and you play netball, let us know. We don't know much. All right. So anything else I missed out? Anything, you know, would you like to give me a nice paper cut and pour lemon juice on it?

14:37 Dr Matt

 Anything else that you'd sort of like to. We're covered in our session. And I don't know how often you get paper cuts in the AFL game. Maybe the coach.

14:44 Dr Mike

 As they're flipping the pages of the playbook. All right. So what I want to do if that's okay and feel free Matt. So as the listener probably knows, we don't really prepare for this. That's the most preparation I've ever put into a podcast. And so when I was well done, honestly, thank you. And when it comes to the rest of the podcast, we sort of just fly by the seat of our pants and try and have it so that the listener is, you know, a fly on the wall to a conversation of two academics who talk about this stuff for a living. And so the first thing I want to talk about is, you know, you don't need to be an athlete like in the analogy. Standing amidst a crowded stadium to immerse yourself in the profound sensoria of the world, you know, all the information that the world is throwing at you every day. So, I mean, you can experience this sitting at home watching Netflix or driving your car to the local shops or finishing. Walking your dog.

15:42 Dr Matt

 Walking your dog. Your dog would be experiencing a huge amount of sensoria as well.

15:47 Dr Mike

 Different, different types. We might refer to that. Particularly smell. Yes. Working on a report, you know, in your office space, like you are going to be experiencing sensory information pretty much like the athlete is in the crowd. And so this information that's coming in, you know, it's a mind boggling amount of information that we don't realize, you know, something like a million bits of information per second. The brain is receiving and the type of information that we are receiving comes in the form of visible light. Sound, pressure, mechanical, chemical, thermal. There's a whole bunch of information that we can receive, integrate, make sense of and possibly react to. And we generally detect them and interpret them using what we call our five senses.

16:36 Dr Matt

 So what are the five senses? Well, you have vision. Yep. Hearing. So sight. Hearing. Smell. Smell. Taste. Yep. Touch. Touch. That's the five. And. No. Gut feeling.

16:50 Dr Mike

 Oh, here we go. Okay. Is that one? Um, is that additive? All right. So, okay. Good point. Those five that everyone knows about that's always spoken about, we have far more than five senses. This is the important thing. So we can detect more than just those things.

17:09 Dr Matt

 So our body can detect things like proprioception. You could argue that's touch, but keep going.

17:16 Dr Mike

 So, well, no. I reckon you could. I'll tell you why. It's mechanical. It is, but it isn't mechanical perception of the external world per se. It can be, but it's often an internal perception. Intra-ception.

17:34 Dr Matt

 Of stretch, pressure, bending. But anyway. But I think you could still argue it's a touch sensor.

17:42 Dr Mike

 So we can also detect our location and position in space and that's proprioception. Right. So your ability to close your eyes and touch your nose sounds simple. Of course I can do it. But if you think about it, when you close your eyes, you can't see where your nose is. You can't feel your nose on your face. Right. You just know where it is. And when you put your hand out in front of you with your eyes closed, how do you know where your hand is without seeing it? And it's simply because the muscles, the tendons, ligaments, joints, they've got different types of receptors that can pick up how bent, stretched, you know, all those types of things. Those particular joints and structures are that feeds back into the brain. So there's proprioception. There's also your body's ability to detect and balance and coordination, which is the vestibular sense. So this is part of inner ear, but also sort of comes together with the proprioception as well. And you've also got the ability to detect possibly damaging stimuli, like nociception. Right.

18:44 Dr Matt

 So that's which is, it's important to highlight different to pain, but we'll touch upon the similarities and differences. We did a podcast on those differences.

18:53 Dr Mike

 Yeah. So if you want the details of that, go to our Nociception versus Pain podcast. And there's also our body's ability to detect internal change. So that means things like heart rate, blood pressure, hunger, thirst. And I would say that that's probably part of gut feeling is that it's an internal change that's happening. And our body can detect it. So, and these are just some examples of the added on ways that we can detect information. But if you stop for a second right now, listener, and if you were to pause us, which you kind of, it's up to you if you want to do that. But if you were to and just stop and try and sit down almost in a meditative state and try and just feel and sense, let's just say sense as many different bits of information coming at you at once, you'll start to notice your feet on the floor and the chair under your bum and the sounds of birds or people in the next room. And then you'll start to see lights and things in your peripheral vision. You start to smell things. You might taste something. All of these senses, you go, wow, there's actually a lot of things coming into my consciousness. But you're only noticing that because you're focusing on that. Like the football player was, he was standing there and he was consciously becoming aware of everything that's happening to him. And so we've got a lot of information coming in in all those senses. And basically they are once there's different types of information, right? We said light, sound, chemical pressure, all these, you know, temperature. But at the end of the day, your brain is locked away in that cranial vault. It doesn't, your brain's never seen the light.

20:38 Dr Matt

 That's interesting. That's interesting, isn't it? Right. That's, I came across this in Bill Bryson book. Yeah. The great paradox of the brain is that everything that you are, everything you've ever experienced, everything that you know, you as you is created and held within your brain. But your brain has never experienced the world. That's right. It's just locked in a black dark box. Yeah. It doesn't have the ability to perceive anything itself. It itself doesn't have the receptors to pick those things up. But it makes sense of everything. Yeah. So it's kind of like a box that just gets information via Morse code. Yes. In this case, the Morse code is electrical signals and just processes it, makes sense of it and then sends more Morse code back out.

21:32 Dr Mike

 Yeah. And I think that's, you know, one of the important points to start with is that while light might be coming in and sound and chemical and touch and pressure and thermal and all those types of things, at the end of the day, the job of the receptors in your body is to detect those stimuli and then transduce it or basically change it into, like you said, a Morse code that the brain can understand. And, you know, I like to use the analogy of if, for example, you were to watch somebody perform an action and you had a piece of paper and a pen and you were to write down what that action was that you saw, you're transducing or transcribing in this case, something you visibly saw. And then you get somebody to verbally tell you what has happened and you again write it down. You're transcribing from audio to written.

22:21 Dr Matt

 Is it transcribe or transduce? Because you kind of change in form. It's both. I'll say it's both.

22:26 Dr Mike

 I'll say you're transducing the information, but the specific ways through transcription, which is written. And the same goes with if you were to taste something and you write down what you tasted and smell, write down what, at the end of the day, you've just turned all these different types of stimuli into one medium of information, which is written. And that's what your receptors do. It turns it into one type of information, which, like you said, is electrical chemical. And that's what's sent from the receptors, which could be external. So in your skin, it could be in your eyes. It could be in your auditory system, could be the tongue, whatever, or internal. So joints, muscles, organs, you know, viscera structures. But at the end of the day, it turns it into an electrical chemical signal that needs to get sent up to the brain.

23:10 Dr Matt

 And so this then turns into what we call something called an action potential. And so when you look at the nervous system broadly, which we're doing today, I know we're spending a bit more time focusing on the brain because it is the complexity of the nervous system. But essentially, the main things which you've just illustrated that the nervous system does are really just three main things. Collecting information from the outside, but also the inside world or inside body. So that collects that information, processes it, and then responds to. And that's really the nervous system, right? Yeah, that's the broad summary. The communication system, very quick. It's a bit different to the endocrine system, which is more so by chemicals. So it's a much quicker system. But essentially, those three functions is what the nervous system does.

24:01 Dr Mike

 Collecting information inside outside body, making sense of it, and then responding to it. Yes. And the electrical chemical signal that's sent from the receptors, what we mean by that is if you think about a term called ions, which is simply just charged atoms and elements. So things that we always hear like electrolytes, you know, oh, I need my electrolytes to stay fit and healthy. Right. One of the reasons why you need electrolytes is one, it helps tell the body where the water should go. That's important. For hydration. For hydration. But two, your excitable cells of your body, like your nervous tissue and your endocrine tissue and your muscle tissue,

24:43 Dr Matt

 they need an appropriate amount of electrolytes. So usually people take electrolytes when they're exercising. Yes.

24:50 Dr Mike

 And so the two excitable tissues that would be playing an important role with exercise is scleromuscles and nerves. And I would argue endocrine too, you know, pumping out adrenaline. So yes, they're important. They need them. And one of the things is that we sweat out electrolytes. We call them salts, but they're synonymous. Electrolytes are salts. And so we need these electrolytes. So we drink them and some examples of sodium, potassium, calcium, magnesium, chloride, right? They're all salts. And the neurons specifically need them to be able to send a signal. What we call the electrical chemical signal. Electrical because these salts are charged. They have either a positive or negative charge associated with them, but also chemicals. So they're chemicals? No. No.

25:39 Dr Matt

 So this is the thing.

25:40 Dr Mike

 It's not like power lines where electrons, it's just the movement of ions. Yes. So in a copper wire, for example, where you're making a telephone call or you're watching your television through wires, you excite electrons, which basically play hot potato with one another, passing the excitement across, right? Okay. But that's not what happens with neurons. With neurons, what you're doing is if you think about the neuron as a wire, you're just throwing positively charged electrolytes into the neuron, down the neuron in a domino like fashion. Okay.

26:16 Dr Matt

 So basically, so you're now talking about the functional components of the nervous system or the functional cells. And these being the neurons. Yep. So these neurons, instead of, they're a cell, but instead of a globular cell that everyone thinks of when they… Oh, like a little ball. They are like ropes. Yeah, they're elongated. And so along the elongated part of this cell called the axon is where this transfer of ions occur. Yes. And you're saying positive things need to come in and then they kind of recalibrate and those positive things kind of go back out. And so usually this action potential is where sodium goes in, followed by potassium going out, and then it gets recalibrated by an enzyme. Yeah.

27:08 Dr Mike

 Is that okay? Yeah, I don't know if that makes sense to people, but without going into detail, which we have in our action potential and graded potential podcast, I suggest having a listen because we break that whole thing down. But the point is that we need electrolytes to send signals and they either jump into or out of the cell depending on whether they want to send the signal or just reset the neuron so it can send another signal. But your point is great. And we need to highlight that is that the neuron is the functional cell of the nervous system. It's of the nervous tissue. The neurons do basically all the communication based work.

27:47 Dr Matt

 So the Morse code send in.

27:49 Dr Mike

 Yes, sending that signal. And so the signal can, like you said earlier, it can go towards the brain or central nervous system to tell it information. It can be in the central nervous system to make sense of the information or it can leave the central nervous system to elicit a change in response to that information. Okay.

28:07 Dr Matt

 And but all of that is neurons. Okay. And should we talk briefly about number here? Yeah, absolutely. So we can obviously we can gravitate to how many is in the brain and the spinal cord. But because we're talking about processing sensory information to begin with. So we're bringing information from the body here. So whether it's touch, whether it's nociception pain or whether it's special sensory. So from eye from ear, all these different receptors in these locations are changing the information into action potential. But then these nerves are carried from the body into the generally it's going to be the spinal cord or the brain stem.

28:48 Dr Mike

 Right. Yeah. So when you say carry, you mean that the nerve or the slash neuron, they're the same thing in our context. The neuron has extensions that carry the signal through there. So these long ropes. The neuron itself doesn't move. Yeah. So the neuron, you're going to have one part of the neuron in the periphery. So for example, and the skin maybe or in the eye or whatever. But then you've got these long, like you said, rope like axons that sort of stretch into the central nervous system.

29:20 Dr Matt

 Spinal cord, for example, brain stem, maybe directly into the brain, which carry that those changes of electrolytes that are jumping into or out of the neuron. And these will be just a nerve impulses. That's the nerve impulse. Yeah. Okay. So when it comes from the body, so we're talking anything below the neck here, all the way down to the feet and arms. These are going to be carried into the spinal cord. So these nerves are going to be carried in essentially by spinal nerves. Okay. And then they come into the spinal cord. The spinal cord is pretty much like an elevator taking things up to the brain. But also when we talk about the motor, so that's movement related, bringing things back down to go out to the body. Okay. So depending on which nerve we're talking about, these could be quite small, but they can also be quite large in number. So when you look at say the largest spinal nerve in the body being the sciatic nerve, which is a big nerve that sits kind of in your bum, behind your bum muscles. It's the largest cell in the body. So the longest cell. Yeah, that's right. So this could be upwards, depends how long your legs are. Yeah. So for you, that's three meters long. Could be anywhere from a meter to a meter and a half. Yeah.

30:32 Dr Mike

 So that's basically how long the cells are. Yeah. This one side, the one neuron that's leaving that spinal cord to, you're talking about the motor neuron in this case, right? Are we talking about the sensory aspect?

30:44 Dr Matt

 Well, the sensory could be even longer depending on what type of sensory, but because in some sensory, if it's going from your toe, it could continue all the way up to your kind of brain stem region until it changes, right? Yeah, but if it's a pain or temperature that usually synapses when it comes in, right? Whereas the dorsal column, that's goes all the way up to the brain stem. Yeah. So that's a long one. So you've got a very long sensory neuron there. Yeah, absolutely.

31:14 Dr Mike

 But in any case, this sciatic nerve, this just show you how big it is.

31:18 Dr Matt

 It's about the size of your thumb in diameter. Yeah. And within that, so if you were to cut it and look through the brain stem, it's going to look like it's a little bit bigger.

31:26 Dr Mike

 And within that, so if you were to cut it and look through it in its trunk, it would have hundreds of thousands of individual axons or neurons or nerves within it. Yes, that make up the nerve. So generally speaking, when you refer to a nerve, the nerve often will have bundles or accumulations of individual neurons. And we tend to call the sciatic nerve, but obviously there's redundancy in the nerve, right? You got multiple neurons because it goes to a multitude of places.

32:00 Dr Matt

 So the sciatic nerve doesn't just go to your toes, for example, it's going to shoot off in all parts of your leg, a thousand directions, both in movement, but also sensory. And just like this is important, just as a note while we're here, this is one way that you can break up when you study the nervous system. Yeah, you can break it up into sensory components and motor components.

32:22 Dr Mike

 Yeah. So what's going up towards the central nervous system?

32:25 Dr Matt

 What's going out away? And so another thing we can add here is we spoke about neurons being the action potential nerve impulse communication cells, the functional unit, the functional unit. But if I again, we cut the sciatic nerve and looked in what you're going to see in there is a lot of white tissue. Right. Now, this is not the best example to because you would have heard the term use your gray matter and white matter. Right. That's referring to the central nervous system. So again, another way we can look at the nervous system is structurally, we can break it into the central nervous system and peripheral nervous system. The central nervous system is generally referred to as the brain and the spinal cord. And brainstem. And brainstem. But because we're outside at the moment with the sciatic nerve, this is the peripheral nervous system. So this is anything outside the brain or spinal cord. Yes. So I've cut the sciatic nerve when looking into it. Okay. A lot of it's white. The reason why whenever we see white matter or white stuff in reference to the nervous system, it's referring to insulation. Yeah. Okay. And so like you gave the example of copper wires, you don't see copper wires, bare copper wires in your house. You don't see it connecting from the wall to your TV or even, you know, coming into your house. Now the reason for that probably twofold. One, you don't want to get electrically zapped because if you were to just touch the copper wire, a bare copper wire, you would get zapped, potentially die. But the main, probably main reason is you'd keep having short, it would short out. Right. It would ground and then you'd have problems. Right. Signal would be lost. The signal would be lost. So a way around this is to insulate it. So just like we see all the cords around a house, they're insulated with plastic, I guess. Right. Yeah. Now our body insulates the nervous system or the axons with insulation as well. Now this would be myelin and the myelin can be made by supportive cells. So they're called, these are called glia. So glia are supportive cells to the neurons. Now in the periphery, this insulating cell is a Schwann cell or Schwann cells. But once you get into the spinal cord or the brain, it now changes a type to oligodendrocytes. Yeah. And so they are very important.

34:51 Dr Mike

 So they make a lot of bulk of the brain, spinal cord and nerves up, but they have an important role of supporting the neurons. Yeah. When I talk about the nervous system to my students, you know, when you look at all the different systems and structures and tissues of the body, you know, they've all got a certain subset of cells that make them that tissue. And when we think of nervous tissue, it's basically just neurons and glia. Right. So neurons.

35:19 Dr Matt

 And I don't know the number now. Like they used to say it was 10 to 1. Yeah, it's probably closer to 3 to 1. 3 to 1.

35:25 Dr Mike

 But that meaning 3 glia to every neuron. Neuron, yeah. So if you think about the neuron is the functional cell, it is the communication cell. I like to think about the analogy of a race car driver and a race car team. So you've got the driver of the race car, F1 race car. That driver in the car is the neuron. Right. They're doing the action. What's the focus of everyone's attention? Is the neuron? Where's it going? How fast is it going? You know, things like that. But if you think about it, that race car is nothing without its pit crew, without its team. They feed the driver. They make sure that the fuel is replenished for the vehicle. They make sure that the car's working, change the tires. All that makes sure that the environment is appropriate for it to function most optimally. That's exactly the function of the glia is it's the pit crew for the neurons. And there's a whole range of glia in the nervous system. Some are different from the central versus the peripheral. But the major types of glia include, like you stated, the Schwann cells and the oligodendrocytes, which are basically sisters of each other. But one is in the peripheral nervous system, one's in the central. And the Schwann cell, which is in the peripheral, like you said, its job is to create the insulation, the myelin. The oligodendrocyte, same thing, creates the insulation, creates the myelin, but for the neurons in the central nervous system. But then you've got other ones like astrocytes, which look like stars. You've got microglia, just real tiny immune cells, epindymal cells, which help produce cerebral spinal fluid. And you've got satellite cells as well. And satellite cells help to just, again, maintain that local environment. So these glia are extremely important.

37:22 Dr Matt

 And again, tend to outnumber the neurons, showing how important they are. Another thing I'll just add with the myelination, sometimes when we look at the speed that the action potential has traveled down, the amount of myelin that we pack around the axon of the nerve, if you can enlarge that myelination, so make it thicker, that would increase the speed that the nerve can conduct, or can push the speed up to the brain and back. And so some information, some sensory, but also motor, you want it to be super fast, as fast as it can possibly be.

37:59 Dr Mike

 So this could be up to 150 meters per second in speed. But if you… So does that mean it takes you one second to feel if you've stubbed your toe?

38:10 Dr Matt

 That's a hot joke because you're very tall. Okay, I'll just keep going. But then if you decrease the myelin, and in some cases we call some axons unmyelinated, they're not truly, but sometimes they're just… Minimally myelin. They just term that. And so they have such minimal myelin that the speed is diminished. You know, in this case, it could be half a meter a second. And so maybe, would you say based on importance? In a way, yes, right? Like the importance of speed.

38:47 Dr Mike

 I'm not saying… No, I don't think it's that. I think it's because of the degree of… The discrepancy when it comes to your ability to… How do I word this? If it's a sensory touch signal and you need a high degree of… This term has fallen out of my head. Discrimination. There we go. Sorry. So it's all about discrimination. So if for sensory information and it's fine touch, you need a high degree of discrimination. So it needs to be a well myelinated neuron because you don't want to lose this important signal. But if it's a relatively unmyelinated, like a nociceptive… Yeah, like a pain one. Yeah. So well, one nociceptive neuron. We can't call it pain. Sorry. Yeah, nociceptive pain. It doesn't need to be discriminative. You just need to know that an area of the body is potentially or is being damaged, right? When you experience a cut on your finger, for example, the pain that you experience tends to be the whole finger, not the very specific location. Okay. And that's why I think the myelination is about how important is the ability to discriminate the sensation.

40:04 Dr Matt

 The speed is important. And I wonder also just to execute the job that it's needing to do. So if you go back to your story at the start, you've got the AFL player that has to coordinate his movements so… Finally. Yeah. So he or she requires information to be sent. Let's say they're running and they want to go into kick a ball. Like all that perfect coordination that needs to take place there needs not only a fast signal to go from your brain down to your muscles to move them in a highly coordinated manner, but they have to also take sensory information back from the muscles and joints so quickly that to do this coordinated movement so well that it has to be traveling at these high, high speeds of 150. Whereas if the player was then to step on a sharp object, he or she just needs to know that they've done something noxious and just say to your brain, hey, we've done something bad here. Just so you know, opposed to having to do it so quickly

41:19 Dr Mike

 to make that job almost to be perfectly executed. I think it's both. I think it has to do with that, the speed and how somebody needs to respond to it. But also I think it's got to do with the discrimination. If you lose some of the signal because of a reduction in myelin, that's not going to be super helpful for you once it reaches the brain. So how, you know, because you're going to have a multitude of neurons that are sending that signal. It's not a single neuron. We, you know, we simplify it to that point.

41:49 Dr Matt

 But if you've got a thousand, how many sensory neurons in a fingertip? Yes, I've got some information here. So let me just pull this.

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43:02 Dr Matt

 We're the home of podcasting. So when you when we talk about sensory density, now as you this would not surprise you at all, but the most highly densely innervated part of your body are your fingertips. Sure. You need that degree of discrimination. Something along the lines of 250 units per centimeter or cubic centimeter in your fingertips.

43:31 Dr Mike

 So if I take a square centimeter of my fingertip, I've got 250 sensory neurons.

43:35 Dr Matt

 If you compare that to your legs, it would be maybe five. Right. So just the in terms of ability to discriminate what type of sensation, but also the separation. So being able to know if it's two point between two points of thing of stimulation, you'd have much better ability at your fingertips, but also, you know, your lips and parts of your face. Compared to your legs and back and so forth.

44:05 Dr Mike

 Yeah. So an experiment you can do at home is get two sharpened pencils and get your housemate, your partner, your parent, whatever, somebody who can verbally respond to you and you get them to close their eyes and you get them to hold their hand out and you put those two, the tips of the two pencils as pretty much as close together as you can without them touching on their hand somewhere, maybe their finger and say, can you feel them as two separate points? And then you continue to bring them closer together. Yeah. So you can you can move them apart or closer together. So a good experiment is you start far away, right? And go, can you feel them as two separate points? And then you bring them closer together until they go, no, I can only feel it as one and you look at on the fingertips and you can probably bring them almost to touching each other before they go. And now it feels like a single point. Do it on their back and you'll find it's like five centimeters. I go, yeah, it feels like one pencil, one pencil tip on my back. And it's a five centimeter difference. And that's just got to do, like you said, with the density of those neurons. And so that's why I also think when it comes to the without dwelling upon it too much, that the myelin sheath and the volume or quantity surrounding it, if you've got less myelin wrapped around the neurons of the fingertips, for example,

45:22 Dr Matt

 if you lose some of that signal, you're going to lose the ability to discriminate. Yeah, and this happens in individuals with deep myelin adding neurological conditions. Multiple sclerosis. Well, not because that's going to be central nervous system. But if you look at certain neuropathies like diabetic neuropathies, Oh, of course. And so they're losing myelin, then they start to lose that sensory perception where they're not as, you know, their ability to have that discrimination is lost. So we've stimulated a receptor from some sort of stimuli. Just with, I think this is a good place just to bring one animal example in. All right. Now, we spoke about the fingernail. So the fingertips and how dense that is. Yeah, the animal. I'm currently reading Ed Yong's book.

46:10 Dr Mike

 Oh, yeah. What's it called? Here we go. Great job. I'll have to find it because you can't shout out Ed Yong. Immense World? Immense World, I think. Immense World? Yeah, I think. Okay, it's called An Immense World by Ed Yong. It came out last year. What's it about? It's very good. First of all, give him a shout out because I love Ed Yong's books.

46:31 Dr Matt

 One of my favorite science writers. So basically this book is looking at the animal kingdom and how in a sensory type of way, how every animal has a very unique way of experience in the world. Yeah. Okay. Now, in terms of tactile, which we're referring to now, one of the most extraordinary animals that have the greatest ability to perceive the world from a mechanical standpoint, so feeling the world, is a star-nosed mole. So it's a mole that almost looks like it's got a starfish as its nose. Yeah. And that is like having all these fingertips on its nose. So it has… Highly dense neurons. So each ray, each finger of the star has 25,000 sensory receptors. Whoa. And so it's like probably as you'd imagine most moles or things that live underground, they probably lose vision because they don't need it as much. I want to say they're completely blind, but their visual perception is probably lost or poorer. But it basically sees by feeling.

47:46 Dr Mike

 So its senses have basically been funneled down into this nose. Yeah. And it picks up, it gives its view of the world. Correct.

47:59 Dr Matt

 Amazing. So the way it perceives the world, like, you know, a big part for us is to see it. Yes.

48:04 Dr Mike

 It would be sensing the world through touch. And it's interesting because even though it's important for us to see the world, our vision isn't that great. And in the sense that the light that we see is, you know, we call it the visible spectrum. It's only the visible human spectrum. Right. And so basically you've got this light that comes off out of the sun and stars. So radiation. It's radiation. Exactly right. And so there's a very narrow field of that radiation, which we call the visible light spectrum, which is ROYGBIV, red, orange, yellow, green, blue, indigo, violet. Right. Anything above red, which is, sorry, anything above red, which is infrared. And anything below violet is ultraviolet. Right. We can't see those. Yeah. Or perceive those. Or perceive.

48:59 Dr Matt

 Yes. But some animals can.

49:01 Dr Mike

 Exactly. Some animals really can. So bees, for example, and other organisms actually see their visible light spectrum sits outside of that. So the point is that I want to make is that we can only detect what our receptors allow for us to detect. So another great example that I use for my students is ultraviolet. Right. The UV, which is UV, UV light that comes from the sun. We cannot detect. We don't have UV receptors in our body. But we can see the impact of UV because we get sunburned and the sunburn is from the UV. We can't detect the sunburn.

49:38 Dr Matt

 We can detect the heat that corresponds with the light from the sun. And that kind of would be infrared. But we are feeling that as heat. Yeah.

49:45 Dr Mike

 Feeling it as heat. That's exactly right. So, but that's not the UV that we're feeling.

49:49 Dr Matt

 But I wonder if UV in a way we do have the ability to perceive, but it is processed in not a sensory manner, but almost like a an output manner. So we have UV that hits the skin and certain cells will. Like melanocytes for example. Yeah, melanocytes, but also it can transfer into, you know, the start of vitamin D. And so whether. That's true actually. We have organelles or certain cellular, you know, components that do perceive UV as something, but don't really tell our brain or our nervous system about it.

50:26 Dr Mike

 But I think perceive is the wrong term. I think perceive is a loaded term that means we've got the ability to have a perception of it, meaning conscious. Yeah. And so when I say, you know, we can't detect it. I mean, that's what you're meaning. You know, that conscious detection. But yes, obviously UV light has its effects on the body. Like you said, you know, the steroids within the skin, it changes them chemically and begins the process of vitamin D synthesis. And like you said, it stimulates the melanocytes to produce melanin, which is like an umbrella for the cells. Or sunscreen. UV damage to the DNA. It's sunscreen for the cells. Exactly. Endogenous sunscreen. So I just wanted to highlight that additional point because I think that's important. We don't detect everything that the world can provide us. Right. So once we've detected it and we've transduced it and we've created this action potential, which again is just electrolytes being thrown into that neuron down along the stretched axon, it's going to enter the central nervous system as you finally highlighted, which is going to be the spinal cord. So that's for the body. Yeah. The brain. And all those entry points are spinal nerves. Yeah. So for example, if something's happening at your feet, legs, trunk, arms and shoulders up to your neck, it's coming in through spinal nerves. But if you've got some sort of sensory detection of the head and neck and maybe a little bit of some internal detection, lungs, digestive heart, that's going to be detected by the cranial nerves.

51:59 Dr Matt

 So that could be vision, smell, hearing, balance, face.

52:04 Dr Mike

 Yeah. And they come in directly into the brain stem and brain. Brain stem and brain. Yep. They're called cranial nerves. Yeah. So all of this sensory information that is coming in and is being detected needs to get

52:14 Dr Matt

 to the central nervous system, which is either brain, brain, nervous. So what we've done here is we've highlighted the peripheral aspect now and we're about to go into central. So this is the structural dichotomy. But we've also done the first part of the function being collecting stimuli. Yes. So pick your stimuli. Doesn't really matter. But we've picked it up from the outside world. This is stimuli and it transduces it on a receptor, makes it into an electrical information.

52:42 Dr Mike

 Now it's sent central or into the central system for step two and that's processing. So the first degree of processing happens in the thalamus. So the thalamus sits deep in the brain. So you've heard of the hypothalamus, which is a bit of tissue that sits under the thalamus, hence the name. But the thalamus is just this paired walnut sort of structure that sits deep in the brain and it's the sorting center, the relay center, the post office, whatever analogy you'd like to use for sensory information. So if you are going to become consciously aware of something, it must go to the thalamus first. And it's great at being able to know, oh, this is a bit of pressure detection coming from the left foot. And then it will send it to the appropriate part of the cerebral cortex, which is the out a few millimeters of the of the cerebrum of the brain. And it sends it to the place that deals with understanding, interpreting and making a decision about that piece of sensory information. And so that's why it sorts it out, because all the information that comes to the thalamus, like you said, has all been transduced and transcribed into a particular one format. But because it knows where it's come from, it knows where it should go. And so the thalamus will send it off to the right place. Now, the right place, again, for conscious awareness is the cortex, the out a few millimeters, but that's broken up into lobes. Frontal, parietal, temporal, occipital, insula. These are the various lobes. And broadly, they've got general functions. So if, for example, you've had some auditory stimuli or input sound, it's going to go to your temporal lobe. If you've had visual, it's going to go to the occipital lobe. If you've had some sort of fine touch, two point discrimination, that's going to go to the parietal lobe. If you've got some information that needs you to make some sort of conscious overriding decision, maybe what you've done is you've read a maths problem. That's going to be visual, so it's going to the occipital. But then the occipital might throw it to the frontal lobe for you to make an overarching decision. The occipital lobe will simply just say, I've seen something. And I can recognize that shape. But then you send it to the frontal lobe that goes, okay, two plus two. What the hell does that mean? So the point here is that while all of these various lobes might have their own broad function, they all speak to one another in one way or another. So if we take this football player, for example, standing there on the pitch, I said that the football player was hearing the crowd, right? Hearing the noise of the crowd. Initially. Initially. Yes, exactly. He was seeing the breeze across the grass. He could see the green grass. He could smell the sweat from the players. And then all of a sudden, he saw the red ball on the background of the blue sky and all of those sensory inputs disappeared. And this is an important thing that our brain does for us all the time, which is something called desensitization. And so, Matt, have you ever woken up, got ready for work, put your socks on your feet, put your shoes on, and then you head out for work and then you just feel your socks in your feet for the rest of the day? Or you got in the car and the music's real loud. Oh, yeah. Yes. And then after a couple of minutes, actually quite a fine volume. Or you say, why was I listening to music this loud? Yes, that's true. But you come home after work and if you've got a kind and generous partner who has decided to cook dinner for the family and you go, oh, that smells delicious. You only smell it for about 10 minutes and then you don't smell it anymore. All these are different types of desensitization, which are actually really, really important functions that the brain does for you subconsciously to basically say, when you first experience it, it's novel and you need to be aware of it because it gives you information about what's happening in and around the world. Right? But if it's there for a long period of time, well, you're already aware of it. You don't need to continuously be aware of this. It's not harmful or damaging. It's not threatening or possibly noxious or anything like that. So the brain goes, you know what? I'm just going to chuck it into the background. So you're not aware of it. Or delete it out.

57:06 Dr Matt

 Or delete it out. And that may be the thalamus there, right?

57:08 Dr Mike

 Just erases or just edits and filters. In part, it's the thalamus, but it's also happening at the area of the interpretation where… Or even the receptor level, right? Yes. So I don't want to go into the detail because that's not what this podcast is about, but some of the receptors, if they continually become stimulated, usually when you stimulate a receptor, it stimulates this molecular switch inside the cell called a G-coupled protein, right? That becomes phosphorylated if it's stimulated too much. And when that's phosphorylated, it's switched off. Okay. And you can't stimulate it anymore. And that's one aspect of desensitization.

57:46 Dr Matt

 So importantly… So that goes to what you're saying about the socks. So you put the socks on and you have these rapidly adapting mechanoreceptors in your

57:55 Dr Mike

 calf or your ankle. Calf? Out top? You're wearing…

58:00 Dr Matt

 Football socks. Knee-high socks. Okay. Okay. Yep. So you're aware that you've compressed… You're a bus driver for a minute. Compressed it to some degree. Yeah. But then because they are rapidly adapting, they switch back off. Yeah.

58:14 Dr Mike

 So you'd no longer have that sense of stimuli anymore. Yeah. Imagine if you felt the clothing on your body at all times.

58:22 Dr Matt

 Yeah. Or imagine… You wouldn't be able to function. And then, yeah, that's right. So not only all the external stimuli, so temperature, wind movement, all the different times of when you touch something, but then at the same time, all the internal stimuli. Right. So blood pressure, peristalsis, heart rate and all that. So your brain just couldn't process it all?

58:44 Dr Mike

 No. Well, it could, but you consciously couldn't. And so I think that's an important concept is desensitization. So all sensory information that goes to your consciousness has the capacity to become desensitized, except one. And that is nociception. That is your body's ability to detect damaging or possibly noxious stimuli. So this is conscious though? Yes. This is your conscious awareness of pain. But by definition, pain has to be conscious. If you're not conscious of pain, you don't have it. Yeah. Okay. So you can't have pain and not experience it because by definition, pain is experiential. Nociception is your body's objective ability to detect… Noxious stimuli. Noxious stimuli. So it could be like chemicals, so an acid, right? It could be mechanical. Maybe a nail is going into your skin. It could be pressure. Someone's holding or squeezing you too tightly. It could be thermal. Maybe it's too hot or too cold. Right? Or inflammatory. Or inflammatory. Which is chemical. Yeah. So all these things are saying possibly, hey, you are or you might get damaged. Tissue damage. And so obviously the nociceptive pathway, which is just like any other sensory pathway, right? Stimulates the receptor, transduces the signal, goes into the central nervous system. So the spinal cord, if it's below the head and neck or the brain stem and brain, if it's above. Okay. And then needs to be going to the thalamus and then needs to be projected to whatever part of the brain for you to be consciously aware of it.

01:00:18 Dr Matt

 The one thing I'll just bring in here, I was going to bring it in a bit earlier, but now we'll work. There's also periods, there's also, well, there's sometimes times where you want to do responses by reflex as well. So it doesn't need to go up to the brain for it to be responded to. Yeah. And these are known as the reflexes. Right? So if you were to have these noxious stimuli and an example would be if you were to touch something hot without necessarily looking at it. So you were to touch me. Yep. You would respond to that noxious stimuli and the response being move your hand away without it processing up to your brain. That's right. Okay. So it can be done at the spinal cord level. Yes. In terms of at least the movement of. Yes. But it will still be processed as, oh, you just touched something hot. Yeah. You would feel the pain after you've dropped the pan. Right. But by the time you've done the response, the reflex has occurred.

01:01:21 Dr Mike

 Yes. That's a great point. And so to, so if we were to just for a second, shelve pain and nociception, just to focus a little bit more about those, the reflexes, if we were to go back to this football player, right? You know, he's looking at the ball, sensory inputs coming in. He goes up to catch the ball in AFL. We call it marking the ball. Right. And let's just say an opponent knocks him something called a hip and shoulder. You put your hip and shoulder into it. You knock him over. He loses his balance. His left leg goes up into the air reflexively. Once that left leg leaves the ground, that sensory information goes into the spinal cord, synapses or speaks to a motor neuron that leaves and goes to the opposing leg and says, hey, plant that foot down. Yeah.

01:02:10 Dr Matt

 Or an interneuron, which is a neuron between the sensory and motor, which would have a, it's kind of got a process in roll.

01:02:18 Dr Mike

 Yeah. Yeah. And so that's a, that's a reflex as well to stop you from falling over immediately. Reflexes still go up to your cortex often so that you can then fine tune and adjust after the fact and make sense of what's happened. There's no point only reflexively responding to things without knowing why or how and what you may need to do it longer term. It's just this immediate save the body response. So back to that nociception. We said that nociception doesn't get desensitized, which means the receptors and the different neurons when they speak to each other, heading up to the brain, they don't dampen the signal.

01:02:58 Dr Matt

 It would be the actual opposite, wouldn't it? So in many cases, if you've got throbbing pain, so okay, nociception, you wouldn't, it would actually, if there is ongoing problem in that area. So let's say you hit your toe, kick your toe or hit it with a hammer. Yeah. Let's use the footy player. Okay, so let's say they twisted their ankle. Yep. Okay. So in that immediate nociceptive moment, they have overstretched the ligaments within their ankle and you would get a fast pain, a fast nociceptive response, which is quick. Oh, I've hurt myself. Okay. So the individual knows they've done something wrong here and that may result them going off the field. But as they go off, they've caused tissue damage, which has resulted in inflammation. And inflammation, we know is swelling, increased blood flow, increased edema, but also increased chemical mediators within the area like prostaglandins, histamines, bradykinins. So these are the chemical mediators, which are continually activating now the C fibers, which are the unmyelinated nerve fibers. So there is the slowest nerve fibers in the body, but it just keeps ramping it up. So instead of adapting and becoming less conscious, it's doing the opposite. It's sensitizing. It's sensitizing. And so you're becoming more and more and more aware of the ankle now to the point when the individual goes home and tries to get some rest, sleep that night, the pain is, well the nociception is overwhelming the alertness part of your, let's say brainstem and can't sleep.

01:04:53 Dr Mike

 You can't think of anything else but the pain. Exactly. Yeah. So the, the bodies, the, the, the neurons that become desensitized, like we said, you know, sort of like the molecular switch that responds to the receptors switches off and the thalamus and other aspects of the cerebral cortex sort of throw it into the background. Right. But with the pain that you experience from the nociception, it's because of a number of reasons. One, like you said, the chemical mediators that are released from damage or potential damage to tissues, you know, what these do, they're little prods and they make it easier for the neurons to fire off. Right. And the thing is that they also actually speak to the glia, the supporting cells of these nociceptive neurons and they make, and they tell them, Hey, you know, something's going on, something's wrong, right? Don't let the neuron ignore it. Okay. So can you please start releasing some inflammatory chemicals, some, some pro excitatory chemicals as well. And the glia, even though they're not even damaged, they start releasing chemicals that say to the new, Hey, don't ignore this. This is a warning system. Protect yourself, protect yourself. Something's wrong. And so it's there so that you one, avoid using that part of the body to help it heal. Which makes sense. Which makes total sense. So that you do something about it. Right. And this is, and this is the reason why I hate the saying no pain, no gain, because if you continue to experience pain, you can continue to ramp it up to this point where maybe the tissue is healed, but the glia and the other cells just continue to release those chemicals. And now you've got a problem called chronic pain where you can't resolve it, or it's very difficult at least to resolve. And so you've now sensitized nociceptors to the point where you just constantly experience pain. So let's just very quickly, before we get off nociception and pain, once that nociceptive signal has gone up to the brain and you're aware, oh, it's the foot, right? Oh, now I'm experiencing negative emotional side effects. So, oh, I don't like this. I'm sad. I'm unhappy. Oh, it's stimulated a sympathetic response, a fight or flight response, which we'll get to in a sec. The nociceptive signal, as it travels up to the cortex, speaks to other areas, which we call the pain matrix, which is a multitude of areas in the brain, which basically, the nociception, basically, makes you have all of that psychosocial aspect of pain, you know, the entire, the psychological side, the emotional side, and the way that it can negatively affect you. And so that is now pain. Pain is the experience, subjective. Nociception is the objective processing of it. So I think, again, that's just an important thing to highlight. And because pain is subjective, you can modulate it through other subjective experiences, by

01:07:57 Dr Matt

 definition. And because that's a processing issue, right? Yeah. I don't mean it's like an issue, like it's a problem with it. But the pain now, you know, is being put into different discrete parts of the body, or the or the brain means the way that it's now interpreted through you as an individual, your culture, your background, all the your experiences will impact how you integrate that information and then kind of respond to it and, and, and potentially how you live with it, right?

01:08:28 Dr Mike

 Totally. You know, often we will have a negative emotional experience associated with pain. But because emotion can be changed, if you're in a happier mood, prior to experiencing the pain, you're going to experience less pain than you were if you were not in a happy mood, if you're in a sad, depressed, angry mood. Again, because it's a subjective experience, it's going to be altered by other subjective experiences.

01:09:00 Dr Matt

 I wonder, this is probably a poor example, but it's just interesting with the way it's thought of is, you know, recently, five weeks ago, my wife and I had a baby. Congratulations. So that process for my wife is obviously one of the most painful things you would experience as a human. I'm sure. But you'll go back to it. Right. Yeah. So there's a degree of happiness, at least at the end. Right. And I know they forget about the pain of it. But I wonder if that is a kind of analogy to where it is the most, well, no, so acceptively, one of the most painful things you'll experience. But because the end product is this beautiful thing, then the subjectiveness of that experience then gets altered. Absolutely.

01:09:50 Dr Mike

 The affective nature of it. Absolutely agree. So I think that's just an important thing to highlight is just that difference between no deception and pain and sensitization versus desensitization. Another thing quickly, just on that topic, because I think we should still talk about it because it's important, is let's just say the footy player does sprain his ankle. What is the first thing he does when he hurts his ankle?

01:10:16 Dr Matt

 Well, he would be probably on the ground and he would be trying to move it or touch it or do something to it to see. Oh, you mean in response to the pain itself, not the whole experience? Yes. Oh, okay. So any time you have that kind of, you know, painful nociceptive response, you generally will rub it or do something to it.

01:10:41 Dr Mike

 Yeah. Like when you fall over and scrape your knee, you sort of rub it. And this is talking about the pain gate theory, which sort of falls in and out of favor as every decade, you know, comes and goes. But basically, simply talking about the fact that a lot of it has to do with trying to desensitize nociceptors by stimulating other sensory receptors. So by stimulating touch receptors and pressure receptors and mechanoreceptors.

01:11:10 Dr Matt

 So would that be at the central peripheral kind of junction?

01:11:15 Dr Mike

 Junction. Yeah. So what you're trying to do is if you've got nociceptors being stimulated peripherally from a sprained ankle or grazed knee, you're going to rub the sensory receptors in those areas because again, all roads lead to Rome, meaning all these sensory neurons enter the spinal cord at the same area-ish. Only so much information. We spoke about you can only be conscious of so much information. And if it's new information, such as new touch information, it might overwhelm the nociceptive or minimize the nociceptive signal. And so it's not going to work long term. But in that moment, rubbing that area might help diminish the pain experienced in that moment because of the pain gate theory.

01:11:59 Dr Matt

 Basically, you're shutting the door, shutting the gate on the nociceptive signal because you're opening the gate for the other sensory signals. Which makes sense because some of those touch mechanoresponsors would travel faster and they potentially have greater number and density. So you may be overwhelming the sensory experience just by doing that. And then you could add other things into it that you likely may see within a dressing room is they're having ice baths and or they rub in deep heat on themselves. And that in many ways, I mean, I'm sure having an ice bath has other implications on things. But just the temperature experience. Yeah. Like stimulating sensory neurons. It's just changing the subjectiveness of it.

01:12:50 Dr Mike

 Right. Have you ever watched the footy and you've seen a player get absolutely smashed, pummeled, destroyed, knocked to the head, huge gashes, wounds, cuts, breaks even. And they keep playing and you go, well, I would be in agony.

01:13:09 Dr Matt

 Right. What's going on? Well, that's the modulating aspect of the nociception experience. So that's where if you look at nociception, I don't want to really get back to what we've done previously. But basically we have the if you were just purely talking about nociception, which is a physiology of processing noxious stimuli, you have again the transduction changing the stimuli into an action potential. You have the transmission. You have the perception. But then you have the modulation, which is descending, the descending part, which has the maybe the central nervous system's ability to go back to the let's say the gate and may release certain endogenous chemicals. They're sometimes referred to as opioids, your own opioid system to downplay the signaling. So kind of in different ways, play with the ion movements, but also the neurotransmitter movements.

01:14:07 Dr Mike

 Yeah, that's right. You've got these descending signals which tend to be mediated by serotonin and noradrenaline, which basically are released in different aspects of the spinal cord and brain. And they just shut the door again for the nociceptive signal to come in. And so when you're in this state of sport excitement, there is a goal that I need to, whether it's literal or metaphorical, I need to achieve. You're going to have one, the conscious overpowering, the subjective overpowering of the pain because you're distracted and you've got other things to focus on. So the pain diminishes in that sense. But also you've got, like you said, the endogenous opioid system mediated by serotonin noradrenaline, which moves down neurons, serotonin producing neurons that shuts the door for the nociceptive signal for the time being. And again, like you said, you go home after the after playing that game. I mean, it's happened to me before.

01:15:06 Dr Matt

 Oh, then you get the pain when you get home. Yeah.

01:15:09 Dr Mike

 I got concussed during a footy game once and I remember coming home and during the game felt nothing apart from being knocked out. I felt nothing. And then that evening, the whole body was just my head, my neck, my back. Everything was just destroyed. Just a lot of pain. All right. Let's move out of nociception and pain. Well, since you'd spoke about it. All right. Do you think it's a time we can just quickly bring up the neurotransmitters? Sure. You don't want to talk about motor first. Or maybe just and then we can talk about them all.

01:15:45 Dr Matt

 Maybe you just mentioned them just as a thing, because I don't want to get bogged down with all the different types. Just some examples of the most common ones. OK. So no, sorry, neurotransmitters are the chemicals that are released between neurons. Neurons don't. So if two neurons want to speak together, they don't touch each other like, I don't know, plug in a power cord into a socket where it just kind of goes across each other. There's actually a gap, a junction, which we call a snap to cleft.

01:16:14 Dr Mike

 What's like us? If I want to transmit information to you. Spit on me. That's one way. You know, I don't just take what's in my head and put it into your head. I have to trans again, transduce that information from neural signals to voice, which crosses the synapse between you and I, which goes into your ears and then turns back into a neural signal again. So it's the same thing, except in this case, instead of words that are verbally spoken, the neurotransmitters.

01:16:44 Dr Matt

 And so these chemicals could be anything from amino acids to proteins to peptides. I guess it's like proteins. But they're smaller. Even gases.

01:16:54 Dr Mike

 Right. Now, one of the first ones that was steroids, steroid based on there, or there any steroid based neurotransmitters? Probably not because they're through bloodstream endocrine.

01:17:06 Dr Matt

 Yeah. But saying that neuro neurotransmitters, which are between neurons, can also go into blood and a good one would be adrenaline or nor adrenaline. Okay. One of the first neurotransmitters to be discovered was acetylcholine. Okay. Okay. And I mean, it probably was known much before, but it didn't really know how these and, you know, many of the early anatomists and physicians thought there were, you know, spirits or animal, yeah, animal fluids or something that are getting transferred through nerves. They obviously knew that nerves did something to change physiology. Right. But they thought that it was the spirit of something that was transferred. But, you know, one of the big discoveries was in the 1921, was in 1921. Not the 1921. Was by Otto Lowey. Yeah. So a German pharmacologist. Yeah. And what he, he was looking at the effect on frog hearts, and he knew at the vagus nerve already and knew that it had a certain effect on the frog heart. Slowing it down. Slowing it down. So when he stimulated, so basically he pulled a frog heart out, put it into a bath of fluid that would provide electrolytes and glucose and so forth and oxygen for the heart to keep beating. But if he stimulated the vagus nerve, he see, he could see that the response to the heart was to slow down. Right. Okay. Now in the other bath, he had cut the vagus nerve off. So what's that called? Vagotomy. Vagotomy. Right. And so what he then did was to take some fluid out of the first bath and pop it into the second bath and found that there was bradycardia as well. Slowing down. So the same effect. And so he turned this vagus stuff. Right. Which is sometimes what I call you.

01:19:05 Dr Mike

 Which just means vagus nerve stuff. Vagus stuff. Right.

01:19:10 Dr Matt

 And so this was the first identification of something that's coming chemically out of a nerve to create a response. And it wasn't until other clinicians, I think in London, actually isolated and then, you know, could find that there was a response to being a neurosurgeon. Acetylcholine being kind of two in one, right? Yeah. Opposed to an amino acid. Yeah. Acetylcholine being acetate and choline as a packaged neurotransmitter. The other good one or other interesting example was adrenaline or epinephrine. And they. Which is the same thing you're saying. They would take extracts from the adrenal gland, specifically the medulla, and they knew that if they could throw it into some tissues, there would be responses. And one of the early treatments for hay fever and asthma was to give people dried bits of adrenal gland. To ingest. To breathe in or ingest or maybe just shoot a liquid into that. Pseudoepigen. Yeah. Right. And the response would be bronchodilite.

01:20:21 Dr Mike

 Opposite.

01:20:22 Dr Matt

 Bronchoconstrict, you mean? No, no, the response would be bronchodilite. So when they got asthma and they're bronchoconstricted.

01:20:28 Dr Mike

 Oh, I thought you meant if you're talking about the nasal. Oh, that's vasoconstrict. Vasoconstrict. Sorry, I thought you meant vasoconstrict. But yes, bronchodilite, vasoconstricts.

01:20:36 Dr Matt

 So that's interesting. I didn't know that. And so that's to some extent is where they discovered adrenaline or neuradoline.

01:20:44 Dr Mike

 So how many neurotransmitters are there? I haven't got a number of me. Have you got a number? I don't have a specific number because I don't think there is one. Yeah. But I think, I mean, to be conservative, dozens. Yeah.

01:20:58 Dr Matt

 Right. If I'm going to, you know, probably guess maybe a hundred. Well, I've got the table that I've got in front of me, which are the most common ones is 12. Yeah. Acetylcholine, adrenaline, noradrenaline, dopamine, those three kind of come together from the same precursor.

01:21:17 Dr Mike

 Serotonin, histamine, glutamate, GABA, glycine, endorphin, but you'd and even nitric oxide, which is a gas more than a. Yeah. Well, that's the thing. So, you know, like I said, there would be dozens. But depending on how you define it, again, many dozens.

01:21:37 Dr Matt

 So with these neurotransmitters, they're usually grouped into either inhibitory or excitatory. So they how they then impact the next neuron. Right.

01:21:44 Dr Mike

 Yes. And, you know, some of both. Right. But, you know, you've got things like glutamate, which is generally always excitatory. You've got things like GABA, which is generally always inhibitory. But then you've got dopamine and acetylcholine, which can do both depending on whether it's well, just depending on the neuron. Right. It doesn't even need to be whether it's central peripheral. So is adrenaline like noradrenaline is excitatory for muscle, but tends to be inhibitory for many sensory neurons. So, OK, we didn't want to focus any more on neurotransmitters. I just wanted to bring it up. Cool. OK. So if we go back to this football player, the information now has hit certain conscious regions of the brain, the cortex. It's hit certain lobes, depending on what the information is. We've spoken about the fact that he's now seen the ball. He's been desensitized to other information. He's now focusing on the ball and now his body's responding and preparing himself to do something motor based, mechanical to move. He wants to catch that ball and he needs to run towards the ball. He needs to move. Right. He needs to prepare himself. And so when you go to perform some sort of motor activity, it needs to begin in the motor cortex. Right. Now, sensory information on just touch, for example, goes to our somatosensory cortex. We spoke about it in detail in the brain episode and we spoke about rewriting the was that the motor cortex or something? Yeah. So you can go back to that. I think that was one of our latest long form episodes. But general fine touch information goes to the somatosensory cortex in the parietal lobe. But motor information begins in the motor cortex, which is in the frontal lobe. And we've spoken about the map of the body in those episodes that the homunculus where we have the parts of the body that either pick up the information or receive the motor output has a map on the brain of those areas. And so if I want to run towards the ball, I need to contract certain muscles of my legs, my feet, my trunk, my arms need to swing and move. And all of this needs to be begin in an area of preparation or the pre motor cortex. So the pre motor cortex has the ability to understand pattern firing, what needs to fire off in what timing. So it allows for you to have rhythmic patterned movement. It does this by speaking directly to the motor cortex, which is simply just the switch to turn on whether a muscle contracts or not. So the pre motor has the pattern. So does that mean for that it needs to have already learned that movement to some degree? Yes, that's why you practice and practice and practice. So you solidify the pattern firing of the pre motor cortex. You can't just sit down and play a piano beautifully. Yeah, that takes a lot of years of refinement. Yeah, and because your pre motor cortex isn't trained to know what note to hit at what time and what pressure to place upon it. That's the pre motor cortex.

01:24:49 Dr Matt

 And it needs to speak to the motor cortex in that patterned way. So in this case, the individual in your story is running. That's a learnt maneuver to jump, to catch, to land, to then run and then to kick. So you have all those have been learnt and they sit somewhere in the pre motor cortex to then feed to the primary motor cortex to just basically code on here's the order of muscle firing that you need to do.

01:25:16 Dr Mike

 Yep, that's right. And so once it's stimulated the motor cortex, it will again action potential, you know, electrolytes rushing into the neurons down motor neurons. And there's generally two motor neurons going from the central nervous system to the muscles that need to contract an upper motor neuron and a lower motor neuron. And so the upper motor neuron tends to go from the part of the motor cortex down to the spinal cord where it's going to exit where it's going to exit. And then the lower is at the spinal cord to the muscle. Right. And so, you know, here we're firing off a whole bunch of muscles. And importantly, when you look at the difference between the upper and lower motor neurons, the lower motor neuron is pretty excitable. Like it wants to fire off all the time. But you don't want muscles to fire off all the time. You want to modulate it. And that's generally the job of the upper motor neuron is it modulates when it's time for the lower motor neuron to fire. So in a way, and this isn't fully correct, but it's a good way to think about it for it to make sense. I think about the lower motor neuron as though it always wants to fire. That's how excitable it is. It's like you and I'm like the upper. Yes. So you modulate the lower. I modulate you.

01:26:28 Dr Matt

 By saying calm down. Now, what would that mean if you were damaged? As the upper? Yeah.

01:26:34 Dr Mike

 Well, then you have complete dominance and there's just mayhem. It's mayhem, right? It's just over here, over there, over there. So muscles are just contract, not in a nice patterned way, but things like fasciculations and this contraction and relaxation. Tone, high tone, upper tone, yeah. And then also your reflexes are high, hypened. That's right. That's right. Because there's nothing modulating that. If the lower motor neuron, if I was damaged, everything would be boring. Nothing would be happening. Right. And so those muscles would be fully flaccid. Right. So if you're in control, floppy and flaccid. I'm so glad you use this analogy. It's making me so happy now. But that's what happens with our reflexes. Upper and lower. Yeah. That's what happens with upper and lower motor neuron damage. Right. So now we've stimulated them. And atrophy. And atrophy. Yes, you're right. So with me, there's still muscle tone. But for you, no, floppy is probably the best descriptor. Floppy and atrophy. Which is the original name of Dr. Mike.

01:27:36 Dr Matt

 Okay. So he's now jumped and he's caught the ball. Here's the great thing. Now that he's caught the ball, sensor information again. Can I interject for a second? Yeah. Now, I imagine that you were going to say something here or you're going to come back to this. Okay. But I'll say it because I just thought it probably needs to be said. So you spoke about pre-motor. Yes. That knows what needs to happen. I hope you're not going to say the thing I want that we're leading into because it's… You're going to say you had the primary motor. Yeah. But before the primary motor is even instructed to move. Yeah.

01:28:12 Dr Mike

 Shouldn't we bring in the basal ganglia, basal nuclei? Okay. Great idea. We'll do that. Do you want me to start with that? Yeah, just broadly. Don't be too detailed. Is that for a good start with that? Because anyway. Okay. So yes, while the pre-motor and motor cortex will just tell the muscle to contract, you need permission for that to happen. And a lot of that permission comes from the basal nuclei or basal ganglia and the thalamus. And there is this motor control mechanism that's deep in the brain that happens between the basal nuclei and the thalamus, which is mediated by dopamine. And simply what happens is there's two pathways, a direct and an indirect pathway. And they're basically about permission. Can I contract? Do I not contract? Can I? Yes, no. And so the motor cortex and pre-motor cortex will speak to the basal ganglia and say, hey, we want to move, can we? And it will send these signals through the direct and indirect pathway that ultimately talk to the thalamus. And if it wants you to move, it will ultimately say, yeah, go ahead. It gives you the permission. But if it also wants you to stop moving, it will also inhibit the movement as well. So there needs to be this fine tuning between the two. Yes, which again is basal nuclei and thalamus. And it's all mediated by dopamine. And it's a start-stop system, right? Start-stop, start-stop. But it allows for this fluid movement so that it's not this jittery, jagged start-stop. It allows for fluid movement and allows for a nice beginning and a nice ending of movement. But if that dopamine goes, diminishes. So it's the neurotransmitter? The neurotransmitter, like Parkinson's disease, right? Which is a loss of dopamine producing neurons. The permission is mishmash. And so it's hard to start moving because you can't get that permission. But also you tend to just suddenly stop and fall over. And often if you're resting, your hand can't have a nice fluid movement. It tends to be shaking because there's not a nice conversation that's been had between the start and stop because the dopamine's diminished. And so that basal nuclei with the thalamus has to give permission for that movement to occur. So I'm glad you brought that up. But don't bring in the signal.

01:30:30 Dr Matt

 So to reiterate, we've had the planned movement in the premotor. All the muscles are told that need to contract, are being told to contract. Send down to the basal nuclei, which then say, yeah, go ahead. Now you have the individual running, jumping, catching the ball. So now they're at the point where they're going to, well, they are receiving sensory information already. So let's just go with a catch.

01:30:51 Dr Mike

 Yes. So here we refer to feedback. And so the feedback is going to be, we spoke about that. He now has this explosion of sensory information, feeling the texture of the ball and the weight of the ball. And this is important because this is feedback that's going to modulate or tweak the next set of movements. So, for example, if that ball is half a kilogram, let's say a pound, the way you catch and hold that ball is going to be different to if it was 20 kilograms or let's just say 35 pounds. Right. It's going to be 42 pounds or whatever the difference is. Right. It's going to be different. And that's because you get feedback. And so what happens is this constant feedback, which doesn't just come from feeling the ball and sensing the ball. It's also your position in space. Are you balanced or off balance? And this has to do with both proprioception and the vestibular system as well. And vision. And vision, where you've got constant feedback coming in and going specifically to the cerebellum, the baby brain, the little brain that sits underneath towards the back of the big brain, basically right behind the pelvis. How many neurons back there? Is it like 40% of the brain? Right. Well, I think you've got just as many neurons in the cerebellum as you do the spinal cord. Oh, really?

01:32:18 Dr Matt

 Yeah. Which is what a billion? Well, I thought it was a lot more, but the brain itself, 80 billion. Right. 86 billion. I thought 40% was in the cerebellum, but.

01:32:30 Dr Mike

 Maybe. Fine. Maybe. I know that there's a lot, especially considering its important role.

01:32:35 Dr Matt

 I was going to throw this earlier in, but when you looked at, say, the human brain compared to an elephant brain, the elephant has three times more neurons than the human brain. Okay. So it's smarter then. And so a lot of people would think that. So the number of neurons just means intelligence. But it's not as simple as that. It's about the conversations those neurons have. What are they doing? What are they there for? Our evolution, our environment that we sit in as humans is a lot different than elephants. Absolutely. And so the majority, not just the majority, but a significant amount of those neurons for an elephant is in the cerebellum to coordinate that big nose.

01:33:13 Dr Mike

 Okay. So it's a trunk. But I think so that then. I was looking at you actually. Also, you're saying that 40% of my neurons are in my cerebellum to coordinate my nose. Right. Inappropriate. Okay. So the cerebellum, its job is balance, coordination, posture and tone. This all has to do with muscles. So muscle balance, coordination, posture, tone. How contracted should a muscle be? And so if you think about this football player, he's caught the ball, he's holding the ball, he knows the weight of the ball, he's landed on his feet. He knows where he is in his position. And so from the bending of the joints, the stretching of the tendons, the contraction of the muscles, he's getting constant feedback from all of these important…

01:34:04 Dr Matt

 And very quickly, right? Very quickly.

01:34:06 Dr Mike

 And these are the fast-firing neurons, 150 meters a second. That's right. Going straight to his cerebellum and his cerebellum is going, aha, this is where I am in my own space. I know where all these limbs are positioned. I know the weight of the ball. And because I've kicked this ball… And how much they're contracted? I've done this maybe 100,000 times before. And I've done this. I know how hard to contract each of these muscles in order to kick that ball appropriately. Because there's no point seeing the goalpost 50 meters away and you do a soft little kick. So it's about where does the ball need to go? And the cerebellum will tweak that. So again, it will tell you how contracted the muscles are of your trunk. So you've got appropriate balance and posture. It also tells how contracted the muscles are in the periphery. So how hard should you kick that ball? And it's helping you coordinate all of it together by constantly going back to the motor cortex and pre-motor cortex, going to the basal nuclei and thalamus. And now you've got this complex interplay of consistent feedback. This is what stops us from just falling onto the ground.

01:35:18 Dr Matt

 If you had no cerebellum, you'd likely be crawling on the floor. And you see that when after the game, everyone's drunk. That inhibits the cerebellum quite significantly.

01:35:28 Dr Mike

 So I read maybe six years ago, because I remember I was teaching the cerebellum and a student said, Oh, does alcohol affect the cerebellum? Because it seems to be. And I'm like, you know what? I don't know the mechanism there. So I read one paper and I haven't read anything that has supported it since, which stated that. And I can't see the mechanism that alcohol or ethanol specifically affected sodium potassium pumps in the cerebellum, more so than sodium potassium pumps elsewhere. OK. Or maybe it affected them all the same. It's just that the cerebellum is more sensitive to those changes. I need to go back and review.

01:36:09 Dr Matt

 But I think a lot of it is central control. And so they don't have they've got a form of ataxia. Yeah. And they just can't. Which is probably with moving, right? Well, yes, but they more centrally driven. So they just don't have a good platform to work off. And so then that's why you see drunks, they walk with a widened stance and they can't do that kind of fine. Walk the line. Walk the line. So the heel to toe kind of.

01:36:35 Dr Mike

 The proprioception. That's why I also do close your eyes and touch your nose. Touch your nose proprioception cerebellum bargain if you have too much alcohol. So now we've got this motor output and we've tweaked it through the cerebellum. And now the player knows how he needs to contract, how strong where he is. And he kicks that ball and he kicks it straight through the uprights because he's done it 10,000 times before. And he's got that pattern pre motor firing and his cerebellum knows how to do this perfectly.

01:37:06 Dr Matt

 And he kicks kicks a goal, wins the game. And then the reaction here is jubilation, excitement. So in his response, now we're going to the autonomic nervous system. Yes. So now we've got a big fight and flight. Yeah. I mean, mind you, probably the whole game is somewhat fight and flight.

01:37:27 Dr Mike

 We didn't. Yeah, we should have touched upon that a lot earlier when it came to. And I'm sorry to interrupt here, but remember at the beginning of the story, he's standing there and he's preparing himself for the unknown. So he's stressed, he's scared, he's frightened. He's got pupils dilating, his breathing's changed, his heart's trying to beat out of his chest because he's anticipating what's going to happen next. And that's because the sensory information that's come up to his cortex for him to be aware. If you're sitting down and you're watching a sunrise, it's non-threatening. There's a degree of, and you can argue where this has come from, degree of beauty. We interpret it as beautiful, nice, non-threatening. But if you're standing there on a football pitch with opponents, they're called opponents, right? They're basically enemies in that moment with a crowd that's roaring so loud. It's grand final. A lot to lose. The sensory information that's coming up isn't just going to those areas of the brain to go, Oh, there's a crowd. Oh, there's noise. Oh, there's some people. It's that crowd needs me to win. Those people are my enemy. I might lose. I might be injured. That's the integration of it then, right? Yes. So as that happens, the thalamus and the cortex, those lobes, will then feed down and speak to the hypothalamus.

01:38:50 Dr Matt

 Maybe the limbic system and macdala. Absolutely. So these are areas that you know that there is maybe more risk associated with the thing, right?

01:38:59 Dr Mike

 Yes, that's right. And so they're all feeding back into just under the thalamus, the hypothalamus, which is the master regulator of the autonomic nervous system. But I want you to define first of all, before we start talking sympathetic specifically, what is the autonomic nervous system and why do we have a basically another nervous system to control, to override or control things that we can't consciously control?

01:39:27 Dr Matt

 This goes back into the functional divisions of the nervous system. So we spoke about you have motor and sensory. If you look at this sensory, we spoke about that you have somatic sensory, which is sensory from generally the body and mostly that a lot of the time is conscious. But then you have visceral sensory, which is information from the internal body. We spoke about that. We spoke about that. A lot of that is again not conscious because you just don't have, I wouldn't say the process and power, but you just you don't have the bandwidth to have all that put into your consciousness. Sure. Now on the other side of the coin is the motor. So we have motor somatic, which you spoke about kicking the ball, running, jumping, catching. But now you have visceral motor, which is controlling all the viscera. Now this is things that again probably better to be unconscious to. So the muscles of the organs, but also the glands of the organs. Yeah. So this would be keeping your heart beating, keeping your blood pressure at a certain level, keeping your breathing at a certain rate, but also the quantity, the volume of air coming in and out, the pupils, also your gut, your urinary tract, all this stuff is motor, but of things you probably don't want to be consciously aware of. Yeah. So you make it automatic. Yeah. Or you make it autonomic. Yes. So this is the autonomic nervous system, which is generally visceral motor. And this will be in kind of two dominant positions, even though they kind of like a seesaw or as you call it a teeter totter, is kind of between a situation of rest and digest, taking it slowly. So this would be for individuals in the crowd or at home watching the event, sitting there eating nachos, drinking beer. That's right. Yeah. Or the people playing, they are in more of a fight and flight response. And so this is the sympathetic versus the parasympathetic.

01:41:24 Dr Mike

 So which one's sympathetic? Sympathetic is the fight and flight. Parasympathetic is the resting and digesting. And they sound like the opposite of each other, right? So like the flip side. And in a way, you're never going to have a lot of people think that you're either sympathetic or you're parasympathetic. But at the end of the day, you're a constant balance. And like you said, a seesaw or teeter totter between the two. Right. All day. It's not like one day you're sympathetic, the other day you're parasympathetic. It's fluctuating hour by hour, minute by minute, second by second. And the whole purpose is to keep you alive in those moments. So specifically, if we focus on the sympathetic nervous system, which is the fight or flight in this scenario. And the neurotransmitter that's dominant here, at least at the organ level, is norepinephrine. Which is important because when I ask my students, I always say to students, you find autonomic nervous system difficult to understand, but it should be easy because you know exactly what happens when you get scared. What happens when you get scared? Or stressed. Oh, my heart rate increases. Yeah. Okay. Why? Oh, I don't know. Well, your body thinks that you're going to die and you need to get out of this moment. You either need to fight or run away. So why would you need to increase your heart rate and its force of contraction to deliver more oxygenated blood to the muscles of the body? Okay, tick. That's done. What else happens? Oh, my breathing changes. I breathe more rapidly. Why? To get more oxygen in to deliver it to the blood so that that fast heart now can deliver it to the muscles of the body. Oh, okay. I go pale. Why? Well, so that the blood in your skin, it's not needed there. Let's constrict it and shunt it to the muscles. So again, it gets more oxygen and nutrients and you can fight or run away. And a sort of side effect of that is if you do get cut or damaged, you're less likely to bleed out. What about my pupils? My pupils dilate. What so you can see more around you in case you see more enemies? It's not high quality. Your acuity is poor. You might be able to focus on it once you see it. Yes. But as for the peripheral, everything in what you need to see is movement, something coming at you happening. Right. You know, so and these are just a couple of examples of what happens when you stimulate that sympathetic nervous system. It keeps you alive in that moment. And that's what's happening with this football player. You know, we call it the adrenaline rush. And so now he's got an adrenaline rush. His system's flooded. The sympathetic nervous system is also speaking directly to the adrenal gland, which then floods the bloodstream with adrenaline. So not only are your neurons releasing adrenaline talking to other neurons and certain organs, your whole system's flooded with adrenaline. And what that means is once you have you can't just stimulate a sympathetic response in one tissue. So it's not like you can you get scared and you can only get pupil dilation. Right. You all all of it happens. And that's because of the conversation with the adrenal gland flooding the bloodstream with adrenaline that goes everywhere. Now, the flip side is the resting, which is probably going to happen, like you said, after the game. You come down from the stress. You're eating the nachos, the donuts, whatever. You know, you feel like you deserve those calories. You're drinking alcohol because, you know, what a day. I do quite a quote deserve this. Now you're in the resting and digesting phase where the more dominant autonomic system here will be the system that's stimulating enzymes to be released from your digestive system so that you can digest. Blood flow will change to your skin and your gut. For example, you're going to have your pupils will constrict. So you can see the person or the food you're eating in front of you. Your breathing will slow down. You don't need that much oxygen going to your bloodstream. So they're the different systems that are sort of and they're all controlled by the hypothalamus. That is that master regulator. So what is there anything else we need to touch upon with the overview of the nervous system and making sense of our case study?

01:45:35 Dr Matt

 Well, I think we've so we I think we've touched upon the main functions that nervous system employees been collecting stimuli, processing, making sense of it, integrating and then responding to. We've kind of compared in contrast the central versus peripheral nervous system. And then we've looked at the functional organization being sensory versus motor, but also added in the autonomic. So I think we've covered the traditional way that the nervous system would be delivered. We've integrated in kind of a story.

01:46:08 Dr Mike

 Hopefully it makes sense. Hopefully it's something that you can go, oh, OK, now I know what you know, we talk about that being responsible for that. But this is in the context and everyday context, but also highlights that just watching a football player, for example, do the thing that they do.

01:46:25 Dr Matt

 It's complex like it is, you know, this is why I mean, complex, just in the motor coordination, looking at the difference between my newborn and my two year old. Oh, yeah. Just taking how long it takes to learn to walk. Yeah. The reason for that. And this is really why you can't bypass these milestones. You can't really put a newborn or a six month old on a, what are they called? Like, you know, there's walking. Oh, yeah. No, not in treadmills. They just kind of they just float around the house with their legs dangling. Oh, yeah. You can't bypass milestones. Your brain has the wire. So true. You know, like something along the lines of 95 percent of my daughter, the oldest daughter's brain volume has developed. So 95 percent of her size is kind of to the point of an adult at a two year old. But in terms of the connections, how it all fits together, the plasticity, this doesn't really mature until late 20s. And this is this is arguably the complexity of the brain. Right. So you may have 80 billion neurons in the brain, but some neurons may have upwards of 10 to 100000 connections. That's right. And it's those connections that make the complexity of the brain. So more connections than stars in the visible universe. Well, let me just find this one for you. I just had a stat that I put down in one cubic centimeter of the cortex. There's more connections than there is stars in the Milky Way. See? Yeah. Insane. So this is part of the reason why a teenager, they still haven't matured their brain and and being exposed to harmful environments, whether it is the physical environment or also the chemical environment and taking drugs and so forth, can be so harmful on the brain because it hasn't developed those networks well enough yet.

01:48:29 Dr Mike

 And we've got the most complex structure in the entire universe in our head. And we still do dumb shit. Right. Yeah.

01:48:39 Dr Matt

 Anyway, and it's part of learning the world, right? It really is. You know, like I just look back to myself. Yeah. You know, you you're so impulsive and so silly. Oh, yeah. You could never be told. Like, I just think back, you could. My parents could tell me and tell me and tell me. But you've got to experience it. I think that's part of it. And there's so many times I look back and go, I could have quite as he died at this age. Absolutely. And you add a particularly I mean, I'm sure it's similar in in the female side, but in the male, you know, boys with more boys with more boys. Oh, yeah. That's the stupidity that just increases. Feeds off each other. But yeah, going back to, you know, my newborn versus my two year old. Yeah. You know, just the time it takes to coordinate walking. Yeah. Is all those things you spoke about just learning the coordination of muscle movement, tone, proprioception, falling over is important. That's right. All these feedbacks have to happen just just to re learn, not relearn, but calibrate that stream of information just takes time. And there's no way you can speed that up. That is for sure. Every day that my newborn, you know, lives another day. Yep. There's a slightly bit more awareness, just a bit more conscious of the world. It's amazing. And it's just, you know, for us, two percent of our body is our brain. Yeah. But 20 percent of the blood and the energy is the brain. Yeah. For my newborn in the moment. 65 percent. Wow. 65 percent of everything it needs to deliver is just for its brain.

01:50:15 Dr Mike

 So it's pretty important is what you're saying. Yeah. Yeah. It's extraordinary. It is extraordinary. And so I hope that the way we delivered this was was helpful and useful for you again. Reach out and contact us if that's the case. We've had a couple of people reach out to us, which I just want to read out some emails. Now we've had some problems with the the contact us page on our website. So if you have sent us an email or a message through the contact us on the on the website, it's probably lost. We're trying to get our IT guys to fix it. But you can send us an email directly. They're starting to come in now. OK, great. Which is GU Biosciences at Gmail dot com. But I just want to read a couple of listener mail if we can. So the first one is from Carrie. So Carrie Kaplan, thank you for sending us an email. It says I'm a visceral specialist trying to incorporate brain health with respiration techniques. I love your videos. Thanks so much. You're doing a great job explaining everything. Thank you so much, Carrie. We love and appreciate this type of feedback. We hope that we help people. We hope that the information is useful. Maybe some analogies we use you can use with your patients or your friends or in study. So got another one here from Katarina. So Katarina Gofken. It's a question and we haven't read any of these, by the way. So let's just see if we can help answer or maybe it's saying, you know, get Matt off the podcast because we're sick of him. Hello, doctors, Mike and Matt. My name is Katarina and I'm a cardiac PCU nurse in the US. I absolutely love your YouTube channel and I spend hours sometimes reviewing different topics with you both. Thank you. Considering the amount of time I love to spend reading and learning, watching to medical content, I can imagine how much time it goes into creating your amazing instruction videos. So for me, it's a lot for Matt. You can tell he doesn't put much effort in. How are you guys such amazing teachers and at the same time stay so physically fit? Well, she's obviously only talking to one of us here. I cannot find the right balance between my love for reading and learning and my need to get up from the table or couch and do some exercise. How do you strike the balance? Looking forward to hearing from you. Thanks. It's a really good question for students because I think it is important to have a balance between your study and everything else, not just exercise. I know it may not be surprising for listeners, but I have ADHD and I get into these moments of hyper focus. And so sometimes I will be sitting there studying reading for six to 10 hours without getting up, not even getting up to eat or go to the bathroom or anything. It's just I get in these moments. So I have to set an alarm and I'm not perfect at it. But one of the things that I do if I know I've got a day that I'm just studying and reading and preparing, which we do often, I set a timer for every 30 minutes. And I've lucky I've got a gym at my house. So every 30 minutes I go into the gym and I do 10 pull ups, 10 push ups, 10 squats. Then I go back to the computer. It takes like a minute. I was going to say the same thing, same thing actually. And then I go back. Maybe barring the pull ups. You could literally do it in your office. Yeah. So I add squat. Did you say squats? Yep. Okay. So I end up doing 100 pull ups, 100 push ups, 100 squats throughout the day. And that's not even my workout. Now, if I'm if I've got the spare time, I'll then go to the gym and do a workout. But at least I've moved and it's not just to stay fit. It's also to take the break from being stationary. Right. And it's also the fact that you actually learn better when you move. Yeah. So for me, blood flow to the brain and so forth. Yeah. And the release of growth factors and things like that. For me, I learn best when I'm walking. So if I've sat down and I've read something and I now need to talk about it in a podcast or do it in a video or lecture it to my students, once I've read it and learned it, I literally get up and go for a walk. And whether I'm at work at the university, I'll walk around campus or I'll go down to the water.

01:54:35 Dr Matt

 Talking to yourself. Yeah. Is that why your neighborhood thinks you're crazy? Correcto. I think that's also part of the reason why we started the podcast is because we knew that students, predominantly students, but now it's broader than that, doing exercise, gym, all sorts of things. And this is a way for them to learn whilst on the move. And so I do all my exercise whilst listening to podcasts because I just find it valuable.

01:55:04 Dr Mike

 Yes, that's why you never work out hard. No, no, but you're right. That's one of the reasons why we did it, right? Because we knew that people need to live a life that's not just at a table.

01:55:15 Dr Matt

 Like you said, Katarina, you know, I think it just has to be in your daily timetable as you would eat. It just has to exercise and moving just has to be part of that. It doesn't have to necessarily be go to the gym for an hour. But as Mike illustrated, as you know, we are instructed in the workplace to every 30 to 40 minutes have a screen break, whether that's just have a stretch, move away, look at the window in that period of time. You could also do those 10 squats, 10 sit ups, 10 push ups, and then you can go back to your study. And just having that break is effective in learning the memory and studying and attention anyway.

01:55:53 Dr Mike

 It's a non-negotiable for me is that I must exercise. I must do some form of movement. Non-negotiable. Like you said, the way you make it like eating, you just have to make it part of your existence, not a value add, because then other things will take precedence. You have to make it non-negotiable.

01:56:16 Dr Matt

 But in that so in that sense, you have to make the exercise something that you enjoy doing. Oh, absolutely. And something that is realistic.

01:56:23 Dr Mike

 Yes. Yeah, exactly. Yeah. Don't put pressure on yourself. So, Matthew, thank you. Listener. I hope you enjoyed it. Listener. Plural. Well, now we've got two. That's good. Send us an email. Contact us. Become our friends. Give us feedback. Five stars. Share. Tell your friends. Subscribe. Subscribe. You know, all that great stuff. We don't ask for money from you. Matt might at some point, but I would never do that to you. Thank you so much.

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