The Brain | Everything You Need to Know

01:27 Dr Mike

Welcome everybody to another episode of Dr. Matt and Dr. Mike's Medical Podcast. I'm your host, Dr. Mike Todorovitch. I'm joined by my co-host and education superstar, Dr. Matthew Barton. How are you, Matt? Good day. It's not more… Is it morning? It is still morning. Good morning, Michael.

02:17 Dr Matt

But good day is fine because you can say that at any part of the day. Why do we say here in Queensland, g'day mate!

02:23 Dr Mike

Wow. A bit of aggression on that face. Which is true to our state. Very nice. We are senior lecturers of anatomy and physiology. We talk to people about health and science and anatomy and physiology. Where? Well, both at university and also abroad. On the street. On the street. I might be doing that. So in the next couple of weeks, I'm going to be presenting at World Science Festival. I'm going to be doing a Q&A with an audience who will ask me questions about how the human body works. You should be equipped for it. Yeah, well, see how I go. And then I've got a camera crew following me around for the day, filming me interacting with, you know, the plebs. Sorry, no, just the public, I should say. Wrong P-word. And just talking to them about why they're at the science festival, what they love about science and health.

03:17 Dr Matt

So it should be good fun. I thought you were going to say asking your students why they're in your lecture.

03:23 Dr Mike

That's a good question. And I'm not going to ask them that because I don't want to hear the lies. We also, you and I, we're in the newspaper on Sunday, weren't we? Who reads the newspaper? Doesn't matter. Australia's best teachers. How much did you pay for that? Look, let's just say that… Was the newspaper a tabloid newspaper? It was. It was the Courier Mail or the Sunday Mail. UK Mirror. I don't know what it's called. That's right.

03:54 Dr Matt

Yeah, Australia's best teachers, man. You and I. Do you think our audience agrees? Let's ask them. So what do you think, guys? Phone in. If they're in 100. Or send an envelope. There we go. With a written response. Is Dr. Matt and Dr. Mike good teachers? That's right.

04:13 Dr Mike

Question mark. PO Box 4000. Anyway, so today we're talking about the brain. And ours aren't working. Well, mine's fine, but yours? Questionable. And we're talking about everything brain related. And so we're going to be going through… This could take some time.

04:32 Dr Matt

The anatomy, we're going to go through the physiology. You're a neuroscience scientist, so you should be all over this.

04:38 Dr Mike

You too. So I would have thought that you would know how to pronounce the word. Brain or neuroscientist? Both. We're both actually neuroscientists. We both did our PhDs in neuroscience. So I would hope…

04:51 Dr Matt

I'm outside the brain, so… Peripheral nervous system. I don't know anything about this thing we're talking about today.

04:58 Dr Mike

Okay, well my PhD was in Parkinson's disease, which is deep. That's a deep part of the brain. And I focused on obviously the basal ganglia and dopamine. So does that mean 80% of today will just be on that? No, no, no. Matt, I love everything brain related. So we're going to give each part fair and optimal time to discuss exactly what it is and why we have it. So I think we should begin with… A definition. A definition. Matt, what does the brain do? And please tell us in 100 words or less. Why don't you ask the AI chatbot? You know, if I start doing this, asking the AI chatbot questions like this, there's going to be no need for you to be on this podcast. Fair point. It might replace Dr. Matt Barton. You just need to put it into voice. Okay. Choose a voice. All right.

05:52 Dr Matt

Well, I'm asking chat GPT in 100 words or less. You know, this week I asked my students if they've used it yet, and most of them hadn't. Wow. And then I told them how to use it. And yeah, I'm not sure if that's going to promote plagiarism in my assignment.

06:06 Dr Mike

Let's see how that looks. All right. So chat GPT has said, so I asked it, what does the brain do? Does Matthew have a… Oh, in 100 words. The brain is the center of the nervous system. I don't know if it means literally or figuratively or functionally. Anyway, the brain is the center of the nervous system and is responsible for controlling and coordinating various functions throughout the body. It receives and processes sensory information, controls movement, regulates automatic functions. Maybe it means autonomic and plays a crucial role in cognitive processes, such as memory, attention, perception and language, composed of billions, billions and billions of neurons. How did it emphasize that? Yeah. In brackets? Yes, that's right. Billions of neurons, glial cells and specialized cells. Schwarzenegger. No, that wasn't Schwarzenegger. You don't know who I was… No? No. I'm sure the dear listener knows exactly who I was copying then. I'm not going to say. I would like the listener to write in. On a different envelope or keep the same one. The brain is a complex organ that allows for us to learn, reason and make decisions based on the information we receive. Overall, the brain is essential for our survival and well-being. That's true. That last part's true. Fair point. Good job, chat GPT. Matt, you're fired. So look, those things are true. It doesn't really necessarily tell us much because it's basically saying anytime you do something… The brain's involved. Yeah, and it's true. So we need to really start… Unless it's a reflex. At least the nervous system will be involved. So I think what we need to do is take our time and go on a tour throughout the brain and start talking about different areas and what they do. But I think it's important to start delving a little bit more into this definition as to what the brain does. And I want to ask you a question. We know that the brain is… Is it me or the chat? Well, let's see how your answer is. I might ask the chat bot if you get it wrong. We know that different parts of the brain perform different functions and a lot of those functions do overlap. So my question to you is how do we know like over, you know, the millennia that we've had a human body, how do we know that, you know,

08:26 Dr Matt

a particular part of the brain plays a particular role? Well, I think in one sense when certain parts are damaged or aren't working well, you can suppose that now because that part is not there or diseased or has been injured, that that correlates to its function. So anything where there's a pathology associated with that area, but possibly also with the advent of neurosurgery where they had the person awake and they were zapping sections… Zapping? Technical term? Electrically stimulating parts of the brain. And then so stimulating an area, then you could potentially also suppose that that's a functional region of the brain.

09:13 Dr Mike

So you're saying in the front end of history, people having certain types of injury, diseases or damage to certain parts of the brain we could see how it presented, how it altered their function, whether it be physical function, processing or cognitive function. And then you're saying more recently due to surgical interventions, we can actually pinpoint parts of the brain and zap them as you said while they're awake and see what changes.

09:38 Dr Matt

Yeah, but I'm guessing that when you said back in the day when things went wrong, we wouldn't have really known exactly where that region was involved. So, you know, we would have had strokes as long as humans have probably been humans, right? Yes. But we wouldn't have known, well, we wouldn't have known that that was related probably to the brain. We wouldn't have probably known what the brain really did. But we could probably see patterns with this particular outcome and then what happens, you know, like face droopy and problems with speech, but they wouldn't have been able to associate that with a region of the brain as we can now.

10:16 Dr Mike

Maybe not, but I think we did know or at least for thousands of years have known that the brain does control much of what we do and think and say and so forth. Because there is evidence, thousands of year old evidence of skulls with boreholes in them. Yeah, so like bleeds with pressure. Yeah. Yeah. And so we knew that relieving some degree of pressure in that cranial vault may have benefited that individual and it may have been due to a knock to the head. They may have had a bleed and they needed to relieve the pressure or it could have been something a bit more pseudoscientific in which they thought we need to let the brain breathe or maybe we need to get to the brain to help this person. But there are boreholes, thousands of years old in skulls. And obviously they didn't have drills back then. So it looks like they took sharp rocks and literally just started scraping the skull back until they went all the way to the brain. Amazing. They had this in ancient Egypt, Ethiopia, many other aspects all throughout the world. Obviously I named two places, both in Africa. I think in America as well. They did have it in the Americas too. So I want to talk about a little bit about the history of this type of surgical intervention, but a little bit more recently and start talking about lobotomies because when we started to play around with the brain, and this is as recent as the 1800s, we still really didn't know what the brain did in very specific parts of the brain did. We knew that like ChatGPT stated that the brain processes sensory information. It allows for us to have some degree of motor activity or movement. And it also allows for us to have cognitive processes like memory, attention, perception and language and so forth. But we really didn't know how that worked. And so what happened was in and around about that, well, for many years, like I said, they put holes in the brain and started fiddling around inside the brain, but they didn't start doing that under the name or banner of science until the 1800s. And so I would say one of the first people to really do this in a quote unquote scientific context, I would claim that it's not very scientific, but under the banner of science was in 1888. So there was a Swiss psychiatrist called Gottlieb, now what's his name, Gottlieb Berkroet. And what he did, and I've obviously butchered that name, so I apologize not to Gottlieb because once you hear what he did. What's his first name? Gottlieb? Gottlieb. Gottlieb. Okay. Swiss, he took six people who had mental illness from an asylum, what they called an insane asylum in the day. But these people obviously had varying degrees of mental illness, probably schizophrenia, probably severe forms of depression. He didn't outline what type of mental illness. So he took those people and he decided to remove parts of their cerebral cortex. Right. He did this by drilling a hole. Through the nose or something?

13:30 Dr Matt

No, no, no, just literally drilling a hole like in the skull. Okay, straight through it. Yeah.

13:36 Dr Mike

And just pulling out parts of the cerebral cortex. Six people. Now, let me tell you the results. He stated that in two of those people, there were no change. In two others, they became more quiet. In one other, they developed severe epilepsy and then died a few days later. And then in the last one, they improved. So from those results, do you feel like this experiment was a success in your eyes? How many in total? Six. Okay. Two no change, two quieter, one epilepsy then died, one improved. Is this a success in your eyes? I guess it depends which individual you are. All right, so if you're Gottlieb, what do you think Gottlieb thought? I think he would have thought yes. Yeah, he said it was a success. And so what he did was he took those results and he presented them to a conference in Berlin and said, hey, colleagues, look what I did. What do you think? And what do you think his colleagues said? Round of applause. No, they said, I probably shouldn't be doing this Gottlieb. Leave it alone. This was not a success. Wonderful. So he left it. Didn't do any more. This was in 1888. Not much happened. So he's a forgotten hero, really? No. So we're going to scrap what Matt just said. Obviously not true. But what had happened was in 1935, someone started to pick it back up again. Right. The drill. And so in 1935, an American neurologist from Yale presented his work at the second neurological conference held in London. 1935. Not Berlin. So decades later, not Berlin. And his experiments were on two chimpanzees, one called Becky, one called Lucy. And he performed lobotomies. Basically, a lobotomy is taking a chunk out of a lobe of the brain, specifically the cortex, often the frontal cortex, because they knew that the frontal cortex or frontal lobe was involved in behavior changes. And this was the main thing that they were trying to alter. So in these people with mental illness, it's a behavioral issue in their eyes. And so if we can change the part of the brain involved in behavior, we can, quote unquote, fix them. And so this is what John Felter did. He took two chimpanzees, Becky and Lucy, and did a lobotomy, the frontal lobe. And he said prior to this, these monkeys were a little bit unruly and had behavioral issues. They'll throw tantrums. And he said that after he performed this lobotomy, that the monkeys were more calm. He said that one of them even acted as though it was very pleasant, as though it had joined, happily joined a cult. Right. And so he presented this work. 1935, Neurological Conference, London. Sitting in the audience was a Portuguese neurologist. His name was Anthony or Anthony Mons. Now, at the end of the conference, Mons loved this presentation, and Mons asked Felter a question. He said, Hey, do you think that we could possibly collaborate, do this in people who had mental illness? And Felter said, No, no, no, no, you shouldn't be doing this. We're more complex. It's a little bit more difficult. Don't do this in humans. So obviously, the Portuguese neurologist Mons, three months later, started to do this in people. And so he started to perform what was the beginning of a very long and very sordid history of lobotomies in human beings. And this is 1930. This is 1935. Right. And so off the back of this, Walter Freeman, another American neurologist, saw what Mons was doing and thought, Hey, I could take this back into the US and do this in people. And started to perform lobotomies. And he did this with a drill for the first 10 years. And then after 10 years, so it's around the 40s, he's like, You know what? I can do this way quicker with an ice pick. I don't have to go straight through the skull. I'll go up through the nose and went up through the nose and the orbital cavity is pretty thin. So he basically put the ice pick up. Through the orbital cavity or through the like the top of the nose, the roof of the nose. Sorry. He went through the orbital cavity. I think he started through the nose and then decided to go through the orbital cavity to the roof of the orbit, the roof of the orbit. So the corner of the eye. So if you're watching this on our YouTube channel, which all of these podcasts now are available on our YouTube channel, Dr. Matt, Dr. Mike, you'll see my finger pointing in the corner of my eye and a little tap with a hammer clock clock clock. Go through the orbital cavity straight into the skull. He would get this done in minutes. Minutes.

18:19 Dr Matt

All right. So and what does he do once the ice pick is in there?

18:22 Dr Mike

Just wiggle it around, pull it back out. OK. What a scientist. Was it was there a particular order to this? Like was it just a wiggle around or I don't look I'm sure that he's a certain amount of centimeters. He would have had a technique. But at the end of the day, it's a very gross, horrible technique. And he was performing this. He thought, you know, I can do this really quickly. There's a lot of mental illness around in the United States at the time, or at least so he thought, I might just do this as like a traveling lobotomy man. And he bought a Volkswagen van. He caught it. His lobotomobile. He actually actually did it in the van. He called it. No, no, he would just travel to the house of people and in his lobotomobile and perform lobotomies. Mostly women. Not sure why. Wasn't a daughter of one of the presidents that I think you're right. Yeah. And I'm not sure if Walter Freeman did it, but he was the most prominent at the time. So in actual fact, between 1930 and 1960, he performed three thousand lobotomies and over 10,000 lobotomies were performed in the U.S. In just this very in this very short period of time. Ten thousand. Well over 10,000. Now he won a Nobel Prize for this. Really? Yeah. For sticking an ice pick through somebody's skull and wiggling it around to get rid. Now the outcome. What was the outcome for these people? Well, again, he stated he actually stated that this procedure allowed people to go back to their childhood. That's what he was saying. I'm bringing people, but it's the only surgical procedure that would bring people's childhood back. But because people started acting infantile. Right. Frontal lobes gone. Yeah. And we know or we can talk about we're going to be talking about the frontal lobe and it's and it's involvement in behavior and complex reasoning and understanding and thought processes and language and motor activity and all those things became depressed or reduced. And he saw that as a wonderful success. But it's not because it also resulted in issues in the behavior would change. Not just be, you know, not just this whatever the behavior was that they wanted was diminished. It would change. People committed suicide afterwards. Yeah. People became unruly. They couldn't regulate their emotions adequately. It was not a success. He did not deserve his Nobel Prize. It was disgusting. And so by the 1960s, which still is pretty, pretty late, right? They were performing these. So thankfully, we don't do this anymore. But like you said, we do have procedures where we can go into the brain and have a look and do certain types of brain stimulation and see what changes. But very rarely, unless there is some sort of cancerous lesion that's growing, do we take brain matter out? Right. So anyway, the point of me telling you this, apart from the interesting sorted history of neuroscience, is that it highlighted that by playing around with certain parts of the brain, you could alter certain functions. And so that's what we're going to do. We're going to go through certain anatomical locations, talk about what they do.

21:43 Dr Matt

So do you think, Matt, considering that you're an embryologist, we should start with the development of the brain? It's going to be early, definitely early. Yeah.

21:55 Dr Mike

But whether you want to outline anything else before we get rolling? Well, a couple of things I want to talk about is how important the brain actually is.

22:02 Dr Matt

I think it's still a couple of factual points. OK.

22:06 Dr Mike

So how big, how heavy? Well, I tell the students it's OK. Heavy wise, it's probably one point two to one point five kilos. Yeah. The size of it is going to be the look at your skull and have a look at what's going to be sitting inside. So it's sort of like a bowl of oatmeal in a way. What does that mean? By consistency? Yes. Yeah, yeah, yeah. Sorry. By consistency, it's it's not solid.

22:33 Dr Matt

Is this oatmeal that is well cooked? Yes. OK.

22:38 Dr Mike

Yeah, you know, like not just oats with milk, but oats, milk, water, put it in the microwave. Boiled for a while. Boiled for a while. Porridge. Porridge. I should have said porridge. It's got that porridge consistency. So if I were to take the brain out of your cranial vault, put on the table, it wouldn't just sit up as a nice solid mat. It would squish down. OK.

22:55 Dr Matt

It would flop. And so how is that protected? Well, first of all, it sits in a vault, like you said. So this is probably the most protective or protected region of the body, right? In terms of cavities. So the skull. Yeah, basically the whole nervous system sits in the probably the most protective cavity of the body. There's many cavities. There's many cavities. But what's the collective for the whole nervous system? The nervous system. No, no, the cavity that it sits in. Is it just like a posterior cavity? Ventral or posterior. OK. Yeah. So the skull is that bony protective layer that wraps the whole brain up. Yeah. And so that is obviously there to protect this vital organ. But we also have the brain that's wrapped up in a layer of connective tissue or layers of connective tissue, which is the meninges. And then, as you said, because it's just it's a heavy thing sitting in a bone, you need it to kind of float.

24:00 Dr Mike

So we also have this fluid that we put in there to also protect and make it buoyant, but also provide certain nutrients. Yeah, absolutely. So you've got protection from bone, protection from connective tissue and protection from fluid. Obviously, all these three things are there to protect it from any sort of injurious agent, whether it may be a physical trauma like a clock to the head, or it could even protect it from chemicals inside the body. These connective tissue layers actually help protect it from things that are floating through the bloodstream. Yeah. So which are probably more dangerous than well, I wouldn't say more dangerous, but probably you're more likely to be exposed to some sort of toxic environment than some sort of physical, at least in today's day and age. I think we should talk about the meninges as a layer. We could start there and move our way in, if you'd like. But I want to first talk a little bit about the brain and its energy demands.

25:04 Dr Matt

Right. So it's a kilo. How much blood does it get? So it gets around about 15%, 15 to 20% of the blood that leaves the heart every minute. 15 to 20%. Yeah. Even though, so this organ is only 2%.

25:19 Dr Mike

2% of our body weight. So it's 2% of our body weight, but it receives 15 to 20% of the blood. But it also receives 20% of our oxygen. So of all the oxygen metabolism that's happening in our body at rest, 20% of it's happening in the brain. So I want to say oxygen metabolism. We don't just take oxygen and use it and spit it out without taking other substrates at the same time. When we use oxygen for energy production, we use glucose at the same time. So what I'm saying is… Predominantly, right? Predominantly, yes. So the brain is metabolically hungry, obviously, because it uses 20% of our oxygen, but also uses 20% of our glucose. So that's really important. The brain wants glucose. That's its primary substrate for energy production. Is that just because it's the most efficient form of producing ATP? Yeah, you get the most ATP, bang for your buck. And also it's super quick to produce ATP. It's obviously not the only substrate for energy that the brain can use, but it's the main one it wants. Now I say that because there's obviously people out there who like to tightly control how much glucose they intake, carbohydrates. Just know that your brain really only wants carbohydrates. So this would be people who have a lower carb diet? Yeah, like Aiken's diet, paleo diet, things like that. Maybe not paleo diet, sorry, carnival diet. There's some crazy diets out there.

26:53 Dr Matt

So these would be… So just restricting carbohydrates, that carbohydrate basically meaning glucose. So does that mean the brain requires another energy source or is it just reliant on the liver to make the glucose endogenously for it? So that's true.

27:07 Dr Mike

So obviously when we don't use the glucose, we store the glucose. And generally the glucose is stored as glycogen in our liver, our kidneys and our muscle cells. Now the muscle cells, it's selfish. That stored glycogen is just for muscle. So it can't release it into the bloodstream for other tissues. But the liver can and the kidneys can, mostly the liver. So the liver, if it's got stored glucose as glycogen, turns it back into glucose, throws it in the bloodstream and it can be delivered to the brain. But our glycogen stores don't last a huge amount of time. If I want to do really intense exercise, I could probably use up all my glucose and glycogen stores within 20 to 30 minutes. Is that right? That quick? Super quick. So then the question is, what are we going to use? Now the thing is that the brain actually stores glycogen. I don't know if you knew that. Do you know where it stores it? Astrocytes. Astrocytes. So these are supportive cells? Yeah. So there's two main types. There's many types, obviously, but two main types of cells in the brain. Neurons that do all the work, the communication. Electrical activity work. Yes. And the glial cells, which are the supporting cells. One type are astrocytes and they're the ones that sort of really take care. They're the best friend of the neuron. Make sure that it's…

28:23 Dr Matt

I'm pretty sure there's a lot of good friends of the neuron. There are. But astrocytes are very important. Regulating the synapse and the blood brain barrier, for instance. Absolutely right.

28:32 Dr Mike

The blood flow to the neurons. Yes. So astrocytes seem to hold onto a bunch of glycogen. And if we, or at least if the brain needs energy, it can release that glycogen. Intracereolone. Yes. But it releases it as lactate, predominantly. Right. Because generally, once glucose and oxygen are utilized, and we need to create more energy, but we don't have enough oxygen available, we know that the textbooks say lactic acid is produced and we utilize that. That's not necessarily the case. We actually always produce lactate with or without oxygen. And it's not lactic acid. It's lactate. So lactate is an energy source and can be produced by tissues of the body with or without oxygen.

29:18 Dr Matt

It doesn't have to just be without oxygen. Does it become more abundant when you don't have oxygen, though? So in cases where you are hypoxic, it usually means lactate will go up, though. That's right. Does that mean the body is trying to produce this to overcome the lack of oxygen? Exactly right.

29:36 Dr Mike

So what I'm saying is that the brain can use glucose for energy and it can use lactate for energy. But it can also use other substrates like ketones.

29:46 Dr Matt

So that would be the reason for why some individuals are having these diets, right? Because they want to go into this metabolic state of producing ketones or the liver producing ketones, right?

29:57 Dr Mike

Yeah. But the whole thing that I find interesting is that obviously when people limit their carbohydrate intake and they're limiting their ability to use glucose for energy, which is a very good way of creating energy, by the way, in the form of ATP. If you run out of that, the body tries to make glucose from non-glucose sources. So it even tries to make glucose when you don't have it. Oh, like reverse it?

30:23 Dr Matt

Yeah. So that means are you saying that the lactate and the ketones that are produced in other areas,

30:32 Dr Mike

it reverses in the brain back up to glucose? That's its aim. Okay. Well, at least in liver cells to begin with. So what happens is if you don't have any glucose or glycogen left in the body, the body tries to make glucose or at least glucose substrates from non-carbohydrate based sources like fatty acids and amino acids. And in doing so, it tends to back up at a particular part of the process, specifically at a part called acetyl-CoA. Is that for both or is that this is specifically for fat metabolism? Fat predominantly, but it does happen with amino acid metabolism as well when you're trying to produce glucose substrates from non-carbohydrate based sources. So amino acids feed into this glycolytic pathway and fatty acids feed into the Krebs cycle. But at the end of the day, they all accumulate at acetyl-CoA. So if you were to Google glycolysis and the Krebs cycle or acetyl-CoA cycle or citric acid cycle or whatever cycle you want to bloody call it, I've got a multitude of names, you'll find that acetyl-CoAs are really important intermediary. Now, in order to make this acetyl-CoA, you need something called oxaloacetate. But when you've got no glucose in the body, oxaloacetate jumps out of this system to turn into glucose. So there's no oxaloacetate. So it all just basically backs up at acetyl-CoA. Now acetyl-CoA, you start to accumulate heaps and heaps and heaps and it snaps together, it forms ketones. These ketones can leave the liver, jump into the bloodstream and go to the brain. There in the brain, it's utilized back as a substrate of glycolysis and produces ATP. So a lot of people, now this is the whole thing, the reason why people limit their carbohydrate and glucose sources is because you make these ketones from fatty acids. Fatty acids come from fat. Fat is what people are trying to lose when they're trying to lose weight. So they quote unquote burn fat, create ketones and there's an energy source. It's not a preferential energy source. It is a backup energy source. How do we know this? It's because if I gave you a jelly bean, it's going to utilize that straight away for the glucose to create ATP. Anyway, but the brain can use ketones. That's my point. So the brain can use glucose, the brain can use lactate, the brain can use ketones. The last thing that it can but really doesn't want to use are fatty acids. So the body really doesn't mind using fatty acids for energy. We know that. Like the muscle doesn't mind using it. Liver doesn't mind using it and so forth. But the brain really doesn't care for it. Do you know why? Why has the brain not evolved? You think that the brain would try and evolve as many backup energy sources as possible, but really does a poor job using fatty acids. Why? Any idea? There's three main reasons why the brain doesn't use fatty acids, why it didn't evolve to use it. When we say the brain, we specifically refer to neurons or tissue within the cranium. Let's say all tissue within the cranium because it is different. You will have glial cells utilizing fatty acids differently to neurons. But let's say brain tissue broadly. Well, imagine being a fat, it crosses the blood-brain barrier, right? Wait, yes. But it needs to be in the blood first to cross the blood-brain barrier. And when it's in the blood, does fat just freely float through the bloodstream? Oh, it's probably bound to a protein. That's right. It's bound to protein and that protein can't cross the blood-brain barrier. So it just can't access it. That's one. But it's actually not the main reason why the brain doesn't use it because fatty acids can cross the blood-brain barrier. So it can disassociate from that albumin or whatever protein is carrying it through the bloodstream. Because remember, it's fat. Fat's not soluble in water. Blood's mostly water. It needs to carry a molecule. That's what we're just talking about. So it can cross the blood-brain barrier if it needs to. But here's the first reason. If you were to take a molecule of glucose and a molecule of fatty acids, glucose metabolism is going to be a better bang for your buck ATP-wise. That's the first thing. Second thing is that you act. And when I say bang for your buck, I mean because people might say, well, you can actually produce more ATP from fatty acids bang for your buck regarding oxygen usage. So you actually use more oxygen. Metabolizing fatty acids and glucose. Exactly. That's important because the brains are very oxygen sensitive. So that's number one. Number two is that when you use this oxygen to make ATP from fatty acids, it produces something called superoxide.

35:24 Dr Matt

Oh, because that's like a free radical. Exactly. That wouldn't be overly good for the brain. Free radicals rusting the brain as it's metabolizing these things.

35:34 Dr Mike

And that's not necessarily a problem for most tissues of the body, but for the brain, it's very sensitive. I mean, most neuro generative diseases have implicated radicals, Parkinson's, Alzheimer's and so forth have implicated free radicals in their pathogenesis. So that's the second reason. And the third reason is simply it's just slower to use fatty acids for energy than glucose.

36:00 Dr Matt

So one uses more oxygen. Is this like universal to all animals with a brain or do you there are some animals that would do this?

36:10 Dr Mike

I don't know. To be honest, I have no idea. So I just wondered if this is an evolved thing that humans have developed their brains. Yes, it has. It has evolved this because you would think it would evolve as many mechanisms as possible for energy consumption. So it uses glucose, it uses lactate, it uses ketones and it can but doesn't preferentially use fatty acids. But the main energy source that it wants is glucose. That's it, my man. Okay, so there is the energy metabolism of the brain. Couple of quick other facts that you want to say. 100 billion neurons.

36:46 Dr Matt

I still don't know that. Come on. Okay. I think I do know. Christopher. Nope.

36:50 Dr Mike

I don't know then. He hosted the original Cosmos series. He's my favorite science communicator of all time. Feynman. Well, okay. He shares the top position as my favorite science communicator with Feynman. Tell me. Carl. Sagan. That's it, man. Billions and billions even though we never said that.

37:19 Dr Matt

That still sounds more like Arnold.

37:21 Dr Mike

No, Arnold would go billions and billions. But Sagan is billions and billions.

37:27 Dr Matt

All right, anyway, so 100 billion neurons. Okay, and are they supported one to one with glia? Or what's the latest number? Because it's kind of… It used to be 10 to 1, right? Glia to neurons or neurons to glia? Yeah, yeah, yeah. Glia to neurons. But I think it's kind of come down to maybe 3 to 1. I don't know.

37:46 Dr Mike

That's a great point to know. But what I do know is that there's 100 billion neurons. Most of these sit in the outer 3 to 4 millimeter layer of the brain called the cortex, which we'll talk about. 80% of them sit there. So it's the most important… Well, it is one of the most important areas of the brain, right? Here's the thing. We may have 100 billion neurons, but it's all about the connections that these neurons make. Synapses. Synapses. And there are trillions upon trillions of possible synapses,

38:22 Dr Matt

meaning there's trillions… So each neuron can communicate with potentially up to 10,000 other neurons. So if you add that complexity of number…

38:31 Dr Mike

Trillions upon trillions of possible conversations can be had. Between them. And they're not being had, but it's possible. This is more possible conversations that your brain can have, or synapses, than there are stars in the known universe.

38:47 Dr Matt

Universe or solar system or galaxy? Universe.

38:50 Dr Mike

Universe. The entire universe. Wow. Yeah. Known universe, because it's obviously infinite.

38:57 Dr Matt

So you could theoretically say we have an infinite number of connections. Because this would also be… This is the plastic aspect of it, right? So these are constantly… Depends how much bottled water you drink. Re-changing. So these synapses could be being pruned off or they could be added. So I guess this is a dynamic situation.

39:18 Dr Mike

Yes. So it allows for us to change constantly. And there's so much stuff going on at the moment with people… There are these wellness people on social media, and they talk about the plasticity of the brain. And it's true. The brain is plastic. But the brain is being remodeled and changes every second of every day. You listening to our conversation is remodeling your brain. It's altering your brain. Just this. For the worst, I think. Maybe. But for people to say, if you want to remodel your brain and reshape it, you have to do this. No, just do a new task or do the same thing over and over. It's going to reshape and remodel your brain.

40:06 Dr Matt

And do you think the brain, in essence, is lazy? So do you think it wants to create networks that it has to do the least amount of energy?

40:19 Dr Mike

So you say lazy, I say energy efficient. So when people say, Matt, you're lazy, you say, no, no, no, I'm just energy efficient. But yes, when you say lazy, you mean energy efficient, as in you're not going to waste energy doing processes

40:34 Dr Matt

when it could be not doing those processes and saving the energy. So they would have certain neural networks that are there to perform a task like visual perception and integration and so forth. And rather than just assume that the one lobe that does a lot of the visual perception being your occipital lobe, there is the possibility that other regions of the brain could do this in theory. But because it's established this network and refined it, it's kind of gone. This is it now. I'm leaving it just to this kind of network pattern.

41:06 Dr Mike

And all the others not necessarily turned off, but they become less active. I mean, that's the exact reason. And you and I wrote a paper of it in the conversation. And I suggest the viewers look it up and read it about why some people left handed. So it talks about laterality. So the reason why we're not proficient in, you know, let's say, writing in both our hands and kicking in both our feet is because the brain doesn't want to waste so much time and energy learning how to write as efficiently with my right hand as I do with my left, because it takes a lot of energy and a lot of time and a lot of space in the brain. So the brain goes, you know what, you writing with your right hand, I'm going to throw it to a specific part in the left hand side of your brain, and that could just deal with writing. I'm not going to fill up another area in the right hand side to deal with left hand writing and so forth with kicking. So you're absolutely right. It just takes certain functions and says you're going to deal with this. Hey, you want to do this? You deal with this part here. But it doesn't mean that it's stuck there. Yeah. And we'll talk about exactly what that means, because I've got some great examples later on about.

42:18 Dr Matt

And that also comes into maybe the use of psychedelics, right? That's they may in that that trip, if you're going to call it that, that it kind of goes back to an earlier stage where more parts of the brain are now being utilized for processing.

42:35 Dr Mike

Or well, yes. And other parts of the brain which mediate where things get thrown to is switched off. And we'll talk about that. Right. Right. Talk about the brain stem, because a part of the brain stem could the reticular formation that is involved in psychedelics, which we should talk about. All right. I think we should. Can we can we start it? I can't believe I'm asking this.

42:56 Dr Matt

Yeah. Are you proposing we actually talk about embryology?

43:00 Dr Mike

Look, I know I'm going to regret it because we're already 40 minutes into the podcast and we haven't actually started anything. Part of the brain. We haven't really. I want to. OK, let me set the scene, because if you set the scene, it's going to be 40 more minutes on embryology. How nervous system starts as a hollow tube, true or false? Yeah, at some point. Oh, here we go. Starts as ectoderm. We're not starting. We're not starting there. We're going to start as a hollow tube.

43:30 Dr Matt

What week are we a hollow tube? Well, let's just call it around 20 days.

43:34 Dr Mike

All right. So at about 20 days, our nervous system is a hollow tube. The third week. OK, so by the time we hit what week four to week five, week six ish, this hollow tube has started to develop these out pockets and these bulges that we turn vesicles.

43:52 Dr Matt

So there's a couple of points I think we should just add here because it is important. This is where we're going to. I won't spend much time here. So we do have this overriding tissue on the embryo and about in the third week. And we'll just call it the ectoderm. And then on the surface of the ectoderm, which is the outer part of the embryo at this point, starts to thicken up and produce a plate called the neural plate. And then pretty simply that just starts to fold up in a wave. And then the wave continues into a circle. And that's probably going to be about day 21 of the embryo. Now, that's important because as it forms the first tube, that's going to be where the tube first closes and then kind of zip shut both quarterly, which is inferiorly. But that's probably not the term we use, right? We can say top and bottom, right? Yeah. And all the way to the front. And so the only reason I'm saying this is because if you have certain if there's certain environmental things that are going maybe awry here within this process, you could have the incompletion of this tube closing. Like enough folic acid? Yeah. So that would be the caudal end. So if the mother is lacking folic acid and folic acid is important for DNA production and replication and so forth. Yeah. And so the way the cells are replicating would be interfered with. And so the posterior end isn't closed well, and that's going to be spina bifida. And there's different arrays of severity for that. But then at the top end, that has to close to and this is probably the most important part to close if you're going to form those vesicles that you spoke of. And if that doesn't close well, then you're going to have probably a term called anencephaly. And as we spoke about in other podcasts, this is this closing part is quite temperature dependent. And if it has been shown if mothers were too hot temperature wise at about this day, day 27, I think, then they might the baby may develop anencephaly. Which is? And this was linked to having a sauna on those days.

46:03 Dr Mike

So what is it though?

46:04 Dr Matt

Anencephaly just basically means without head. Right. Yeah. So the whole back section of the so that it will be a non viable delivery. But the back end of the head would be effectively still open.

46:18 Dr Mike

Wow. OK. And so zipping it shut top and bottom involves some very important environmental signals. Yes. At around about day 21. Yeah, that's basically where it closes. OK. So once we've zipped it up at around about four to five weeks ish, we start to develop these bulging and outpockets. They are what we could turn vesicles. And so these these various vesicles are obviously important because they are precursors to important parts of the brain. And can we go through them? Sure. OK. So if we go from top to bottom, which I know is not the best term, but let's just go from top to we've got to imagine getting an A4 piece of paper or just a piece of paper. And you fold it, fold it into a tube and then imagine that there's going to be five parts that pocket out from top to bottom at the very top. The first bulge we call the telencephalon.

47:11 Dr Matt

Not yet. So if you if you. Oh, here we go. If you start with a three. You start with a three.

47:16 Dr Mike

Three hours going to bypass the. Oh, OK. It sort of means nothing.

47:21 Dr Matt

OK. Well, it's just the the the point here is that the tube itself, you brought this up. That's all the time we have, folks. We're getting there. So go. So this is an interesting point, I think. The tube itself, the neuro tube is all the cells that are ever made in the central nervous system comes out of the line of this tube. So all the neurons will migrate out and produce all the all the cells within the brain. And then this tube that it's and what it's left with is the it's going to be the CSF system, the system that makes the cerebral spinal fluid. And so the the final cells that are there to help create the CSF, but also push the CSF along that those glial cells which left behind. And then they're the glial cells that have those finger projections called the epindymal cells. So that kind of just illustrates that the tube makes all the basically all the the cells that are in the central nervous system as well. And this is including the spinal cord. Yeah. So at the front end of the tube that's closed, as you said, after probably week four or five, you get these dilations, three dilations, which we call the primary brain vesicles. And that would be the the proencephalon, the mesencephalon and the rumbencephalon. And they're kind of named for shape or their location. All right.

48:48 Dr Mike

And then we go to the secondary, which you were referring to. Yes. So there was no point bringing up those three. I knew it. All right. So.

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50:19 Dr Matt

Terms apply. We talk about that they're important for the CSF system. That's the only reason why I spoke about it.

50:29 Dr Mike

Yeah, whatever. So the very top one, Telencephalon.

50:33 Dr Matt

Telly means at a distance. So like telephone or television. Means at the end. So it's going away from the initial proencephalon.

50:42 Dr Mike

And so if we break it up to the prefix and suffix, they all end in encephalon. Right. Which means brain. So telencephalon is like you said, the end of the brain. And so this turns into something called the cerebrum. Yeah, the cerebrum.

51:00 Dr Matt

And so the middle part of this, which is the dilation points, would become the lateral ventricles. So that's the fluid within the cerebrum. So all the different horns of the lateral ventricles. Yes. They will form the different five regions of the cerebrum.

51:17 Dr Mike

Yeah. So obviously we've got a hollow tube that's had these out pockets. And the out pockets produce the important parts of the brain. But the hollow inside is retained. These are the ventricles of the brain. And there's four ventricles, which, and like Matt said, two of them, the lateral ventricles that sit within deep within the cerebrum now. And it's just the hollow inside of that tube. And like Matt said, they have certain cells called epindymal cells that produce cerebral spinal fluid that helps float the brain, like we were saying before, but also helps bring important nutrients and also take important metabolic byproducts away. So we've got the cerebrum. Do you want to talk about the cerebrum now and then keep moving? No, I think we just do it. Let's complete it and then come back to the response. So underneath the telencephalon is the diencephalon. And di just means between because it's sitting. Because if you think about it, the diencephalon becomes the thalamus and hypothalamus. And epithalamus. And epithalamus. Good point. And when you look at the thalamus, hypothalamus and epithalamus, it sits between the cerebrum and the brainstem. So that's what's called the diencephalon because it's just sitting there between. Then underneath the diencephalon, you've got the mesencephalon. And this is the midbrain. So this is the very top of the brainstem. Underneath that, you've got the metencephalon, which, sorry, I should say mes means middle. Middle, yeah. And it is because there's five parts and this is the third one. So it sits right in the middle. Then you've got metencephalon, which is the pons and cerebellum. And does met mean towards the back? Not sure. I think met means behind. And so that makes sense because the pons and specifically the cerebellum juts out behind and sits behind and underneath the brain. And then you've got the myelencephalon. And the myelencephalon, myel actually means marrow. It's the core, which is interesting because this is the medulla. Medulla. And medulla also means marrow and core. And this is the lowest or bottom part of the brainstem. So mesencephalon, metencephalon and myencephalon, these juttings or outpockets or bulges or vesicles or whatever you want to call them, they make up the three parts of the brainstem plus the cerebellum.

53:38 Dr Matt

Yeah. And all those regions that is the hollow sections that you said is part of the CSF, they have their own distinct regions. So the telencephalon, as we said, is the lateral ventricles. Then the diencephalon will be the third ventricle. Then we go down to the, what was the mesencephalon, that's going to be the cerebral aqueduct. And then we go into the last part of the brainstem, which is the pons cerebellum and the medulla, which is going to be the fourth ventricle. Perfect. And then it continues into the spinal cord as the central canal. Beautiful. And so this is important for the way that the CSF will flow through the central nervous system.

54:16 Dr Mike

Yeah, wonderful. So what we've highlighted is some of the most important parts of the brain, the cerebrum, the thalamus, hypothalamus, epithalamus, midbrain, pons, medulla and cerebellum. And we're going to talk about those. We will also endeavor to do very specific detailed podcasts on each and every one. But today is going to be an overview. So let's first start with the at 51 minutes. Let's first start with the cerebrum. So the cerebrum is the largest part of the brain. When you look at the brain, you're looking predominantly at the cerebrum and it looks like a bowl of worms.

54:50 Dr Matt

There's a whole bunch of undulations. And so why is that there?

54:54 Dr Mike

So that's there. So when you look at it, it looks like there's a whole bunch of hills and valleys and that is there to increase the surface area of the brain. So in actual fact, if you were to flatten out all these undulations, the brain would be about 2.5 square meters, which is like a pillowcase size. Right. So if you were to sort of flatten it out, it would look and wouldn't look, but it would be the size of a pillowcase. So that's pillowcases. How big? 2.5 square meters. Because remember, it opens up. So if you were to cut it and then open up, that's 2.5 square meters. So the brain has this increased surface area to obviously fit more neurons so we can have more synapses and do more things. So that's obviously important. So the bump up is called a gyrus singular or gyri plural. And the dip down is called a sulcus singular or sulci plural.

55:49 Dr Matt

And when you're looking at that, that's a kebab called in Greece. Delicious. It's called a gyros.

55:56 Dr Mike

Is that from the same thing? Maybe. It's a good point. Don't know. Not Greek. So I've never been to Greece, actually. Unfortunately.

56:06 Dr Matt

But you grew up in Melbourne though, didn't you? What's that supposed to mean?

56:09 Dr Mike

Which has got a big Greek population. The second biggest Greek population outside of Greece. There's probably more Greek people in Melbourne than there are in Greece, to be honest. But I'm not Greek. I've got a lot of Greek friends. Anyway, don't know why we're talking about that. You can ask them. I will ask them. So that's the cerebrum. The cerebrum actually is made up of two hemispheres.

56:34 Dr Matt

So what were the bulges again? So gyrus. So they're the folds. That's the bump up. And what's the valley? That's a sulcus or sulci. And what's the real deep ones? Fissure.

56:45 Dr Mike

And when you look superficially at the brain, you'll see a couple of really prominent sulci, gyri and fissures. So for example…

56:53 Dr Matt

Start with the fissure, the one that runs right in the middle, because that's going to give you the two hemispheres. From front to back? No, the one that's run…

56:59 Dr Mike

From front to back. Yeah. The longitudinal fissure. The longitudinal. Yeah. So it runs longitudinally from the front of the brain to the back of the brain, and it separates the two hemispheres of the brain left and right. So your brain is actually… Your cerebrum is actually separated. So you can pull them apart. They're actually held together through these highways. The white matter. The white matter tracks. And that's an important point, because if you were to cut into the cerebrum, you would see just with your eyes parts of the brain that look grey and parts that look white. And this is what we term grey matter and white matter.

57:34 Dr Matt

What is this? The white is because it's fatty. Why? Why is it fatty? It needs insulation. Why? We've talked about this before. Not today.

57:45 Dr Mike

So no one knows. Yeah, go on.

57:47 Dr Matt

This is the insulation of the wires in your brain. The wires being the neurons. The neurons are electrical sending cells. Electrical chemical, yeah. And they send it just like power lines, you know, as close as we can to analogy. And if we don't have a insulation around it, it will lose its charge, let's just say. And so it needs to be wrapped up, particularly if you want to send the signal in a long distance. So anywhere where you see the neuron being projected to a long distance away, the most efficient way to keep that charge or that signal within the neuron, we wrap it up with a fatty substance called myelin. And so wherever you see white or white matter within the central nervous system, it's just basically meaning it's myelinated, it's insulated, and it's a tract or it's going somewhere.

58:41 Dr Mike

So to put that simply, the white matter are the highways. Okay. All right.

58:48 Dr Matt

And obviously, the grey is absent of that myelin. And so it usually means that's where the connections or the bodies are of the neurons.

58:55 Dr Mike

Yeah. So if you were to look at a picture of a neuron or just draw a neuron up, you've got the body and you've got the axon. And obviously, either side, you've got dendrites and areas that receive and send signals and throw signals out. But you've got the body and you've got the highways. Similar to you've got your house and you've got the roads you drive on. At the house is where you do all the important stuff, right? That's where you talk to people, tweet, watch TV, read your books. Wait, Matt does not. I do all these in the car. And then you've got the highways. So all you do is just transport from one place to the next. So at the house, this analogy is going to fall down once we have automated cars. So in the house, there's no fat, right? There's no fat surrounding it because there's no signal sent, right? But once you're on the road, that's where you got the fatty myelin sheath that's surrounding it. That's dangerous for the cars. It's like the bitumen. It's not like the roads are covered in lard. And everyone's slipping and sliding all over the place. All right. Okay. The analogy has fallen short. But at the end of the day, white matter, they're the highways covered in myelin. The gray matter, they're simply the bodies. That's where integration, that's where neurons talk to one another. You know, that's the synapses, the bodies, so forth. All right. So you can see that when you cut into a cerebrum. And like I said, you see the white matter. You can see the white matter and the gray matter. In actual fact, what you'll find is the gray matter are more superficial and the white matter are deeper. So what that tells you is that all the integration, all the making sense, all the thinking and processes and, you know, the seat of consciousness and cognition, it's all done on the outer few millimetre layers of the cerebrum that we call the cortex. The deeper stuff, it just, they're highways taking information to and from the cortex. You can break up the cerebrum. And the body. Yes. Yeah. Yes, yes, yes. So you can break up the cerebrum and the cortex into what we call lobes. And so most of the cerebrum are the lobes. And even though the cerebrum is going to have most of the neurons of the brain, 80% of those neurons sit just in that cortex. So it shows you how important the cortex is for all these processes. So let's talk about these lobes. Okay. There are four to five lobes. We've got a lobe that sits at the very front of the brain called the frontal lobe. Makes sense. We've got two lobes. Well named, well named. We've got a lobe that sits behind the frontal lobe called the parietal lobe. Because they're paired? Yes, because they're paired. And then you've got just next to your ears, the temporal lobes or next to your temples.

01:01:40 Dr Matt

And then right at the back, you've got the occipital lobe. Seat of wisdom. Sorry? Seat of wisdom. The temporal lobes. Well, I think it's the temp, I could be wrong here, but I'm just going to go with it. I think the temple, the temples is the first region that of your hair that goes gray. And it was supposed to be the first one that I can see. Because my yeah, good point. Your temples gray? No, they're red. So I'm not. Anyway, let me finish this. That was assumed that that's the seat of wisdom or that, you know, as you start to get older and wiser, because that's the area that grays first. That's where you are. The wise. The wise. The temples. So I'm guessing, not evidence based, I'm guessing that the bone was labeled or named before

01:02:29 Dr Mike

the brain. Probably right. I think the lobes are named after the bones. The bones. Yeah.

01:02:35 Dr Matt

So frontal, parietal, occipital and temporal. And then we have a deeper one that's insular. Yeah. So the ground level. If you were to fold the temporal lobe or poles back a bit, so try to pull it apart a bit, then you'll see the insular deeper to it.

01:02:53 Dr Mike

That's right. So let's talk about these five lobes. Now maybe let's do a bit of anatomy so people can sort of understand where these lobes are. We spoke about the longitudinal fissure separating the left and right hemispheres. But if you have a look going perpendicular to that, so going from left ear to right ear, you've actually got something called the central sulcus. Not as deep as the fissure. No. The central sulcus separates out the frontal lobe from the parietal lobe behind it. Separating out the frontal lobe from the temporal lobe is a fissure called the Sylvania fissure. I won't use those terms anymore. Lateral fissure? Lateral. Yeah. Okay. Is there any? Lateral sulcus. Okay. Lateral sulcus. Is there any demarcation point for the parietal from the occipital? Parietal occipital. The parietal occipital sulcus. Okay. So there we go. So you've got these grooves or divots or valleys that will separate one part from or one lobe from the next. Yep. Start with the frontal lobe. Start with the frontal. Alright. To the front. Okay. So frontal lobe is the way I like to think about it generally is it's the action cortex. Okay. The end. So move on. Right. No. So it's actually anytime you want, anytime you want to do something, you're recruiting the frontal lobe. Like move. Like, well, okay. So anytime you want to move or demonstrate something. So demonstrate how you feel, demonstrate what you want to pick up or say or see. Say is good. So speech. It's all frontal lobe. So if we were to have a look at that central sulcus going from ear to ear, just in front of that sulcus, because remember you've got hills and valleys. So in front of a valley, you can have a hill and in front of that hill, you're going to have a valley and in front of that, you're going to have it, you know, so it goes. So in front of the central sulcus, you've got a hill called a gyrus and it's called the pre. Because it's in front of, yeah. Central. Pre-central. Gyrus. Brilliant. And the pre-central gyrus is a very important part of the frontal lobe. It's what we call the primary motor cortex. So the primary motor cortex actually has a whole map of the muscles of the body on it. So it's the areas of the body that can be controlled by muscles. And there are going to be certain areas that have a larger part of the brain map to it. What's this map called? The motor homunculus. And if you Google motor homunculus, you'll see a weird looking thing that looks like Matt naked and parts of it are exaggerated. And these exaggerated parts. Thank you. No, not that part. That's the sensory homunculus. But the. I was referring to my tongue. Oh, yes. True. So the motor homunculus, the bigger the area dedicated to it in the brain means the more fine tuning of the motor activity can perform. So think about fingertips, for example. You can do a lot of fine motor movement with your fingertips and therefore you're going to have a larger part of your brain dedicated to it. Same with your tongue, for example, but not so much your back. Not so much your arm. It will be for those other areas. So the whole point of the primary motor cortex is that when you want to initiate a movement, it must come from this area. So let's just say I want to play the piano. I know I need to contract muscles of my hand. And so this signal will begin in the primary motor cortex. It has a part in a northern muscles that's required to play the piano. Well, this is when you start recruiting a part of the motor cortex that sits next to the primary motor cortex called the pre-motor motor association cortex. And the motor association cortex does have the pre-motor cortex associated with it and another association cortex.

01:06:52 Dr Matt

But let's just call it the motor association. This is learnt movement, right? So you've already done this movement once, I shouldn't say once, many times before and you've kind of refined that movement out. And so it has an idea of what that movement is required or what needs to be done to execute

01:07:08 Dr Mike

it. Yeah, so far, again, let's just say I want to play the piano. I know I need to contract the muscles of my fingers. I need to recruit the primary motor cortex because it has a map of the muscles of my fingers. But I need to tell those muscles to contract in a patterned, coordinated, sequenced manner. This is where, like you said, we pull on a part of the brain here called the motor association

01:07:28 Dr Matt

cortex that has that map or I should say that has that sequence. Is this grossly termed? I know it's incorrect, but many people will know this term as like the muscle memory.

01:07:39 Dr Mike

Yes. Yeah. So it basically has circuitry that tells us what gets contracted in what moment at what

01:07:46 Dr Matt

time so that we can actually play the piano. And this is just why you get better and better as you do that task. Yeah.

01:07:52 Dr Mike

The more times. And if you have a look at the motor association cortex, there's going to be a part for fine hand movement, for eye movement, for speech. And it sits right next to the part of the primary motor cortex that deals with the muscles

01:08:07 Dr Matt

for those areas. So with that, you have an area that's for the eye fields, for instance. And then when you're doing a task, maybe an exercise. Well, this is part of playing the piano, I assume. You have to read the because technically, I'm guessing as a pianist, you shouldn't look at your hands, but you're reading the notes from the book that's sitting in front. So your eyes are needing to coordinate that reading motion whilst you're playing the piano.

01:08:41 Dr Mike

And so that coordination of reading. It's called your frontal eye field.

01:08:46 Dr Matt

That comes from there. And if you were to have an injury there, then you would be able to technically understand the words, but you wouldn't be able to coordinate the eyes to read well.

01:08:55 Dr Mike

And that might make reading a difficult task. Exactly right. So in this frontal lobe, we've got the primary motor cortex, we've got the association motor cortex, and then we've got other association areas, which actually have other separate designated regions. So for example, for frontal eye field, like you said, for tracking, which is important, like reading the music, like you said, and we've also got another area called Brockers

01:09:18 Dr Matt

area. Are these terms becoming less used now? Probably, but we're using them.

01:09:25 Dr Mike

So that would be like an association area, like the eye fields, but this is for speech. Yes. So the speech association area is Brockers area.

01:09:32 Dr Matt

This would be executing speech, right? Not necessarily understanding it. This is delivering the speech. So you have to coordinate your breathing whilst coordinating all the muscles to not only move the vocal cords, but to shape the sounds.

01:09:47 Dr Mike

Speech production. So that's Brockers area speech production. So you've got damage here, some lesion here.

01:09:53 Dr Matt

It's called Brockers aphasia. And that's kind of goes well with the outcome of a stroke usually, right? Because as we know with stroke, we have that acronym that's called FAST, F-A-S-T. Thank you, Matthew, for spelling it. F face, A arms, S speech, T just means time. But the reason why I'm saying face, arms, speech is because when you have a clot, which is usually like, I don't know, 80% of all strokes come from a clot. There's the greatest likelihood that the blood vessel that goes to the frontal lobe or that part of the frontal lobe being the middle cerebral artery stops blood going to this region of the motor cortex, which controls your face muscles, top part of your arm and the muscles that coordinate speech, which is that Brockers area. And that's why some of the early signs of stroke is slurred speech is because it's kind of stopping those neurons that you spoke about in that homoculus, but it's in that region of the body.

01:11:01 Dr Mike

Yeah, yeah. So we've got motor cortex primary association motor cortex, Brockers area for speech production, frontal eye field for eye tracking, and we've got the pre frontal cortex. The pre frontal cortex actually takes up the bulk of the frontal lobe and the frontal cortex is an extremely important area when it comes to cognition, higher order reasoning, understanding. Think of this is where the lobotomies were causing big issues, right? Think of those behavior instance. Yes, behavior, emotions, understanding. It's really important to know. So for example, the way I behave with you is going to be very different to the way I behave with my wife or the way I behave with my boss at work. It's all different. And to understand how your behavior should change in different social arenas is controlled by the frontal lobe. And that's a really nice way I think of highlighting its importance because when people had frontal lobotomies or when the frontal lobe has been damaged like it has been in the past, I think Phineas Gage was a Phineas Gage back in the 1800s making a railway. They blew up the railroad.

01:12:13 Dr Matt

I don't think he blew it up. I think he was like TNT. He was trying to force a iron bar into a shell that had dynamite or gunpowder. So it blew up. But not the whole railway. I think it just shot the steel rod out of the canister.

01:12:30 Dr Mike

It shot it into his face and into his frontal lobe and they got rid of it and he survived and they said that his behavior changed significantly. So we went from being a very cool, calm, collected young man to a very debaucherous…

01:12:45 Dr Matt

I think he swore a lot. So he's not cute. It was very similar to it.

01:12:48 Dr Mike

I've never swore on this podcast. That's a lie. Is it? Anyway, should wait. Watch me on the tennis court. So frontal lobe, really important when it comes to behavior, emotion, complex reasoning, higher order processing and so forth. Do you have anything else for the frontal lobe?

01:13:05 Dr Matt

Let's move on because we've got five to cover.

01:13:08 Dr Mike

That's just one region. Yeah. So parietal lobe. This is sitting behind the frontal lobe. So while the frontal lobe is the action cortex, the parietal lobe is…

01:13:17 Dr Matt

So what was the sulcus that separates it? The central sulcus. Okay. And so like we saw, the motor was pre-central gyrus. So I'm guessing the first one back will be post-central gyrus.

01:13:28 Dr Mike

Beautiful. And that is going to be an important part of the parietal lobe. Broadly… Another homoculus. Just wait. I haven't said… So I said the frontal lobe is the action cortex. The parietal lobe is the understanding cortex. Understanding, not feeling. It is feeling as part, but understanding is the most important. I feel you, but I don't understand you. Great. I'm going to leave that there. So yes, there is a post-central gyrus and the post-central gyrus does have a map of the body, but not for motor activity. Sensory. For sensory. So what we're saying is that the motor cortex in the frontal lobe sent information down and out of the nervous system.

01:14:11 Dr Matt

Oh, you know what we forgot? What? We forgot to say that the opposite side of the brain controls the opposite side of the

01:14:18 Dr Mike

body. I was going to do it right at the end. Oh, okay. But we can do that in a sec. I spoiled it. That's okay. No, no, no. You didn't spoil it. You just spoiled everything else. The parietal lobe, yes, the post-central gyrus, it's there for sensory information. So it's receiving information from the body. The pre-central gyrus in the frontal lobe, that's sending information out to the body. So very different in that sense. So similar to the frontal lobe, there's a primary somatosensory cortex for receiving information and there's an association somatosensory cortex, just like the motor. So the primary somatosensory cortex, that's receiving real basic information about the environment. So it's going to be information about touch, pressure, pain, movement, proprioception. So proprioception is knowing where you are in your own space. So if you close your eyes and I say touch your nose, you can do it. And the reason why you can do it is because you know where your hand is in its space. You don't have to look at your hand and follow it to tell it where to go. Very different to if I gave you a dart and said throw this onto a dartboard. You have to actually look at the dartboard and you have to throw it because that dartboard is not a part of you. So you don't know where it is in its own space. You need the visual cues to be able to do it. But all the muscles, joints, tendons, ligaments of our bodies have receptors that tell us how bent, contracted, taut, tight, all these different areas are so we know where we sit in our own space. That's proprioception. So that's the type of information the primary somatosensory cortex is receiving. But it tells us information, real basic stuff about the size of an object, the weight of an object, the texture of an object, but doesn't tell us what the object is. So if I put my hands in my pocket and I feel something like a coin, like a coin, it's telling me information about the size of the coin, the weight of the coin, the texture of the coin, the temperature of the coin and so forth. Or just distinguishing a coin from, I don't know, a pin. No well the thing is all you can distinguish are the textural weight size differences, but you don't know it's a coin, you don't know it's a pin yet. Through which one? The somatosensory cortex. It does not tell you that. The part right next to it, the association cortex, that then helps you understand that sensory information. And what it does is it pulls on other areas. So it receives information from the visual cortex, from other parts of, from other cortices, from your memory banks, from the limbic system for emotion and goes, okay, I felt this before. Last time I felt it, it was a coin. I felt coins like this before. I felt a 20 cent piece feel like this. It's a 20 cent piece. Things like that, right? So that's the association cortex. Now similar to the frontal lobe, there's also a language area, but this is for understanding language, right? So when you're reading text or hearing words being spoken, this is sensory. So it comes in, makes sense of it. This is called the verniches area or verniches. This is also runs into the temporal lobe as well. Absolutely. So it's sort of a combination of front, a parietal temporal lobe, but it's basically language understanding. So brockers, speech production, verniches, speech understanding or language understanding. So you could deliver the speech, but you may be incoherent, which is just basically me. Exactly. So if you had a lesion or damage in just brockers, speech production would be difficult, but you understand everything someone is saying. But if you had a lesion in verniches, then being able to produce, so being able to understand speech is difficult, but you'd be able to speak. No problem. But it could be words that makes no sense to context. True. Because if you can't understand language, how do you speak it properly? All right. Anything else you'd like to say about the parietal lobe? No, I like it. Okay. So we've done that. Now let's go to temporal lobe. This one's pretty easy. So we've only got one real true function here. There's obviously other things, but in addition to understanding language from verniches,

01:18:42 Dr Matt

it's hearing. Yeah. So primary auditory cortex. Yeah. So processes, the information that's coming from our ears, but probably that also goes, like you said, up to the parietal lobe to make deeper meaning of the words and the language and so forth. That's right. Yeah. But also olfaction, so smell. So this would work with the insular cortex, which we haven't got to yet, but smell maybe more the gross stimuli, but not again knowing what that means.

01:19:16 Dr Mike

Yeah. You have to pull on other areas, other association areas to do that. Anything else for the temporal lobe? No. Okay. Then occipital lobe, sitting right at the back, very broadly. Visual. Yeah, visual. Visual field. So visual information. So occipital, sorry, our eyes are obviously receiving light information in the form of photons, which it then transduces into electrical signals down the optic nerve and then via the retina and then sends this signal back to the occipital lobe. And again, very similar to what we were saying, there's going to be primary areas and association

01:19:52 Dr Matt

areas and it works just like all those others. And so we haven't got to this yet, but you would have like a sensory filter, which we'll talk about, which is the thalamus that will receive a lot of the gross visual stimuli and that kind of filters off a lot of information that's not important. So let's say if you were in a busy area reading, you don't want to have all these visual things outside reading the book, right? So the thalamus removes a lot of that. Background info. So it kind of filters that out and then your visual cortex will get things that it will then make sense of, but then your association areas will then put the meaning to those visual stimuli. So let's say the putting the face together. So you now know that that's looking at yourself. Yes. Me.

01:20:44 Dr Mike

There's a difference to just colors and tones. Yes, that's right. Yeah, exactly. Perfect. So that's the occipital lobe and then you've got that insula like you said, if you were to reflect away the temporal lobe, you'll see the insula and that's important for taste and certain parts of memory, memory, pain, and yeah, so gestation, which is obviously taste. Which I wonder is taste one of the best associated sensory stimuli that goes with memory. That's a good question.

01:21:22 Dr Matt

I don't know, but I do know that no, because the smell would have to be a big part of that too. Well, they kind of are the same, right?

01:21:29 Dr Mike

Technically. That's true. Yeah. Good point. Good point.

01:21:34 Dr Matt

Yeah, I'm not sure. Anyway, that's probably yeah, let's let's. Okay, we'll leave that.

01:21:38 Dr Mike

We've got so much to go through. All right. So that's the insula. So important for pain, emotion, taste, all those types of things. So they're the lobes. So these are parts of the cerebrum. The cerebrum does have other deeper areas to it.

01:21:52 Dr Matt

So for example, it has parts, parts of the basal nuclei. I think you should mention this, or you are mentioning it technically.

01:22:00 Dr Mike

Talk a bit more about this. Basal nuclei? Yeah. Okay.

01:22:06 Dr Matt

Talk about it in the context of the cerebrum. Particularly motor. Okay. So deep to motor control. We'll do a podcast just on the basal nuclei.

01:22:13 Dr Mike

Yes. The basal nuclei is what it sounds like a group of neurons.

01:22:19 Dr Matt

So nuclei group of neurons, basal sitting deep. And sometimes this is referred to a ganglia.

01:22:27 Dr Mike

That's right. Which is not correct. Right. Its job basically is to control motor movement, or I should say fine tune motor movement. So if we think about playing that piano, I said the muscle contraction must begin at the primary motor cortex. The pattern sequence of muscle firing must work in concert with the premotor and association cortex. But in order to know how to coordinate the flexor extensors. Yeah. So firstly to initiate the whole. So handbrake off. Yes. Handbrake off, handbrake on. When do you start the motion? When do you finish the motion? Because at the end of the day, a lot of motor neurons that are shooting down from the motor cortex, they want to fire all the time. You actually really have to tell them to stop firing. And so you need the basal ganglia to help modulate the firing off. When to start, when to stop. And it's not just starting and stopping, but starting and stopping plays an important role in how smooth the movement actually is. If you keep starting and stopping, it's very jagged. So at the end of the day, the basal nuclei is very important for starting and stopping motor movement and smoothing it out. And it does this using dopamine. And so without going into the weeds, because we should do a whole episode on it, there's two major pathways called a direct and indirect pathway. Both use dopamine, but at the end of the day, one's a start pathway, one's a stop pathway. And they both work in concert to allow for you to know when to start, when to stop, and

01:24:02 Dr Matt

how to smooth the movement out. And when this area goes wrong, and a good example of this would be Parkinson's disease, which would result in a difficulty initiating movement and then smooth it out, hence the

01:24:14 Dr Mike

jerkiness. And the reason why that happens is Parkinson's disease is a loss of dopamine producing neurons. And you need dopamine is the key here for the basal nuclei. So once you start losing 80% and more of your dopamine, which is what happens in Parkinson's, you can't modulate the starting and stopping and smoothing out. So like you said, it's very hard for a person with Parkinson's disease to start walking. But once they start, start walking, it's not too bad. So it's the starting. But they also have very shaky movements.

01:24:46 Dr Matt

At rest, right? But that disappears on movement, right?

01:24:50 Dr Mike

Exactly right. Yeah. So that makes total sense when it comes to the basal nuclei. So that is parts of this basal nuclei are embedded within the cerebrum. And other parts include the limbic system. So parts of limbic system, which is part of emotion, is also part of the cerebrum.

01:25:06 Dr Matt

Is it just promoting emotion or creating emotion or is it emotion with memory?

01:25:12 Dr Mike

Maybe all of that. Yeah. I wouldn't be confident being very specific there because I wouldn't be surprised if it's all of the above. So that's the cerebrum. We said part of the telencephalon. The diencephalon now, which is underneath that, this is going to be the thalamus, hypothalamus and epithalamus. So you gave us a really nice introduction to the thalamus. This sits really deep in the brain. It's like an egg or two eggs next to each other. Yeah, like two eggs next to each other. The thalamus is that sorting center, the post office, the relay center for all sensory information. In actual fact, anytime you want to be consciously aware of sensory information, it must go through the thalamus first because the thalamus tells it where to go and like you said, filters out what needs to go where. And that's basically what the thalamus does. So for example, if I were to pick this mug up, the fact that I know I'm consciously touching this mug is because sensory information has been sent down sensory neurons, gone into my spinal cord, up to the brain and has entered the thalamus. Here it sends it off through a third order neuron to go to the part of the somatosensory cortex that deals with my hand. So I go, oh, I'm holding something in my hand. So again, I think a point that we probably didn't necessarily highlight when we spoke about the cerebrum and cortex was that the cortex is the seat of consciousness. So you will only be aware of something consciously if it gets to the cortex. If it doesn't get to the cortex, you have no idea that it happened. So it is the seat of consciousness. The neurons in the cortex are the substrate of consciousness. But let's now go back to the thalamus, epithalamus, hypothalamus. We said the thalamus is the sorting center, relay center. Perfect. What about the epithalamus, which obviously sits on the thalamus or above?

01:27:12 Dr Matt

What does that even do? Well, the epithalamus has different regions to it.

01:27:15 Dr Mike

So one of them being the pineal gland, which gets calcified obviously when you have two no, sorry. I was going to say that's where your soul is. That's right. That's what Rene Descasse said, wasn't it? He thought that the pineal gland was the seat of the soul. I can't be sure. They don't know what they're talking about.

01:27:33 Dr Matt

That's why it's called the third eye. Yeah, okay. Well it kind of is a third eye in a way. Oh, here we go.

01:27:40 Dr Mike

Okay, pseudoscience by Dr. Matt Nook.

01:27:41 Dr Matt

Because visual information, some of that information is sent to this region, which is important for regulating or being aware of light versus dark. Does it control melatonin? Well yes. So melatonin is a neurotransmitter that would be released from this particular region of the epithalamus. And so by receiving light stimuli, it would potentially tell you or your brain has the capacity to then know this is the part of my 24 hour period of the light or the day and vice versa going into the dark cycle where you probably are wanting to release more melatonin, which is going to be important for sleep. Yeah, absolutely. All right, so that's the epithalamus. Anything else in the epithalamus you want to talk about? I think that's the main one I know. Yeah, no, I think that's probably the most important part. And then the hypothalamus, which is under the thalamus. And all these, well not so much epithalamus, but all these we will do a separate podcast in because they're so complex and they require a lot of time. But we can quickly run through the main functions of the hypothalamus.

01:28:48 Dr Mike

Yeah, I always tell students it's the master regulator or master control center of two major things. One, the endocrine system. So that's hormones. Hormones. And two, the autonomic nervous system. So that's fight and flight and rest digest. Yeah.

01:29:03 Dr Matt

It can do this because the hypothalamus communicates with a little protrusion called the? Infundibulone. Yes. Or the stork. Which connects to the?

01:29:15 Dr Mike

Pituitary gland. That's right. And there's an anterior and posterior aspect of the pituitary gland. That's very important for hormone production and release. Both anterior and posterior pituitary gland or aspects of the pituitary gland release different hormones. We're not going to go through them here because that's an endocrine podcast. I think we've done that. We have. But they are extensions or at least the posterior pituitary gland is a true extension of the hypothalamus. The other is not.

01:29:39 Dr Matt

It comes from your nose. What? It comes from your nose. That's not jumping.

01:29:44 Dr Mike

And migrates back. Which I think is amazing. So the posterior aspect of the pituitary is neuroendocrine. So it's part of the brain and the anterior is true endocrine tissue. Not part of the brain. Yeah. But the hypothalamus can control the release of its hormones anyway. So the hypothalamus is the control center for hormone release. That's one. And then autonomic nervous system.

01:30:06 Dr Matt

So does it control it or just a master regulator of it? Well both. As in like does it kind of dictate it or do you like for instance we know that two important functions of the autonomic nervous system is regulating heart rate, blood speed, blood pressure, breathing. But they kind of controlled more in the brain stem.

01:30:31 Dr Mike

But does that mean the hypothalamus has like this conductor like control over it? Yes. It has override capacity. So let's just say so basic functioning of the heart and respiration for example does occur in the brain stem. This is just the basic firing. You know setting respiratory rate, setting heart rate. But then if something happens and you need to override it to speed it up or slow it down or make the heart contract harder or faster or tell the airways to constrict or dilate, this comes from the hypothalamus. It overrides because it says hey too important here we're running away from a tiger. We need more air coming in. We need the heart to pump harder and faster. That doesn't come from the brain stem that comes from hypothalamus.

01:31:17 Dr Matt

So that is the diencephalon. We also have with the hypothalamus temperature control which I've just gone through this with my students recently. It plays a role in when you have certain things going wrong in the body like an infection or too much inflammation. It can be the hypothalamus that is be told that we've got some kind of issue happening in the body. We need to turn up the temperature. So this is known as a fever. And interestingly the chemical that plays an important role with the change in the thermostat. So what the hypothalamus keeps the body temperature at which is somewhere between 36.6 and 37.2 degrees Celsius. If you throw certain chemical mediators at it, it will create its own prostaglandin and that will bump up the set point which can then lead to a temperature. And interestingly the enzyme that does this is cyclooxygenase but I think it's a third one which is not the other two. That's another podcast. So this is where certain drugs like paracetamol have a role in blocking this one but has no

01:32:35 Dr Mike

other role in the other tox enzymes. Gotcha. Interesting. So the reason why paracetamol is a good antipyretic but isn't necessarily… That's why it's still considered an NSAID technically. Well it's not an anti-inflammatory.

01:32:47 Dr Matt

It's not an anti-inflammatory but it does block a tox enzyme. Yeah. But it's wrapped up in that group.

01:32:56 Dr Mike

It is. It is a cox inhibitor but not all cox inhibitors are NSAIDs. That's right.

01:33:01 Dr Matt

Anyway that's a bit of a digression. Food intake, food behavior, water balance.

01:33:06 Dr Mike

Thirst, yes very true.

01:33:10 Dr Matt

Hypothalamus does a lot for malaria. That's why we're going to do a podcast on it.

01:33:13 Dr Mike

Next. Mesencephalon, this is the midbrain. This is the very top of the brain stem. We're going to talk about it in the context of the rest of the brain stem. So let's move on. Metencephalon which is the pons which is the middle part of the brain stem and cerebellum. So let's now talk about the cerebellum for a little bit. Cerebellum is that small brain located at the back of the big brain. Hence why it's called cerebellum. That literally means smaller brain. Does it? Yeah man it does. And the cerebellum, do you know what cerebellum does? I hope so. As a general? Because I have no idea. Yeah no I do know what it does.

01:33:51 Dr Matt

I say three things. Coordinates movement, oh not coordinates it just smooths off movement.

01:33:57 Dr Mike

Balance and muscle tone. Yeah tone, balance and coordination. That's what I say. So muscle, so all of which have to do with proprioception and your body's ability to fine tune motor movement.

01:34:11 Dr Matt

Do you know how you were playing the piano? So for you to execute moving the keys with your fingers, let's just say first you have the idea of the playing the piano that comes from your pre-motor which sends a signal to then your prior motor which then will send signals to your fingers and so forth that's going to start playing. But first it has to send something down to the basal ganglia to turn the handbrake off. Ask for permission to move. And then refine what the firing will be like.

01:34:50 Dr Mike

But before it gets to your hand does it have to first go to the cerebellum? No, so what happens is the cerebellum receives proprioceptive information from the muscles. As you're starting?

01:35:00 Dr Matt

It tells you how hard you should be pressing the keys. So you're now starting to depress the keys with your fingers but as you're moving your fingers you're getting proprioceptive changes within your fingers and your joints and your muscles that are getting sent back up. This will go into your cerebellum which has an idea of how much movement's happening with what your pre-motor and so forth is expecting to happen.

01:35:31 Dr Mike

And then this modulates the motor going down to your fingers to make the movement smooth. Yeah, it's the thing that really tells you hey don't smash the keys and tells you about where your hand location is, all that type of stuff. The example I use is, and it's a very simplistic example, but you know you've got to help a friend move house and they say hey go pick that box up for me, just be careful it's really heavy. So you walk up to it, you bend your knees, you grab it, you're preparing to lift something heavy and then as you stand up you realise they pointed the wrong box, it's empty. Now you've prepared yourself to contract every bloody muscle you've got in your legs, your back, everything. But you don't flip yourself backwards, you don't jump up into the air because of this strong contraction that you've prepared yourself for. So what is going on? And it's because of the cerebellum. It's fine tuned, it says hey you don't need to contract as hard, so the muscle tone. Hey don't get off balance because this box is light, so balance and posture because it maintains certain contractile rigidity of the core muscles within your trunk. So tone, balance, posture and coordination, so being able to lift that box in a way that's appropriate, that's what that cerebellum does. And it does it because it also has a homunculus, so a map of the body, but it's flipped, it's upside down. So if I were to take your cerebellum out, cut it and look into it, you'd see the grey amount of the water. Is it your whole body or is it just your core, like just your axis? No, it's your trunk and your limbs. Okay. Yeah.

01:37:08 Dr Matt

So that's your cerebellum basically. And so one of the important clinical points here, or maybe not clinical points, but things that people have experienced I'm presuming is alcohol will have an inhibitory effect to the cerebellum and therefore coordination of movement is impacted by the consumption of alcohol. And this is probably part of the reason why in America, this is what I understand, they still do this in America where they get their alcohol testing regime is to do the toe to heel, walk the line, right? Johnny Cash. Opposed to say Australia, we do the breathalyzer. But if you are trying to do this quite challenging motor procedure of putting your heel to your toe along a line without falling over, if you are inebriated with alcohol, the coordination and the proprioceptive motor control is being inhibited by in your cerebellum.

01:38:07 Dr Mike

And so you get like an ataxia, which is a floppy core, right? That's right. Which was your nickname in high school. Floppy core. Yeah. You're right. And that cerebellar ataxia is interesting because there are some people who are born with a genetic mutation, which causes them to have cerebellar ataxia. And they can't walk if they close their eyes, which shows how important the visual system is at overriding proprioception. But yes, so the cerebellum, very important. Why does alcohol mess around with the cerebellum? I read this, I remember I had this asked, this question was asked to me by a student maybe like eight years ago. And the answer I, well, I investigated the answer and there was preliminary evidence then but I haven't found any more that it specifically inhibited sodium potassium pumps in the cerebellum. Only there. That's the thing that I didn't understand. Why there? What maybe it's just there is more sensitive, maybe it inhibits them globally, but the cerebellum is just more sensitive to sodium potassium pump inhibition compared to other areas, maybe. Not sure. All right. So the cerebellum, that's metencephalon and then myelencephalon is the medulla, the lowest part of the brainstem, which means now we can talk about the midbrain, the pons and the medulla all together as the brainstem. And this is where we will be finishing our conversation. Well, we're going to talk about the brainstem, but this we're going to be, well, we might talk about a couple of other things, but okay, brainstem. A couple of really important things. It's the deepest part of the brain. It's the lowest part of the brain before we hit the spinal cord. The deepest or just the lowest extension of? Yeah, I could. Yeah, okay. Lowest extension of. The thing is that the myelencephalon means core, deep, pith, medulla. Medulla means deep. Anyway, whatever. Just going off the Latinization of it. So it is the lowest part of the brain before we hit the spinal.

01:40:08 Dr Matt

The whole of the skull. Yes. Which is called the big hole. Literally. The foramum magnum. And as soon as the part of the brainstem goes through that hole, it becomes the spinal cord.

01:40:19 Dr Mike

Great. So brainstem. People call it the lizard brain, which is a horrible name because. Insulting to lizards. Well, probably insulting to us more so. It's not just this old, unchanged, archaic structure which performs these real basic functions. It does perform what we term probably basic functions, but they're not basic at all. It controls heart rate, like we said, respiratory rate. Two extremely important processes that if they didn't work would be dead. But it also has a whole bunch of different reflexes associated with the head and neck, which are extremely important. The brainstem is the primary area that has the nuclei of most of our cranial nerves. Probably the only.

01:41:12 Dr Matt

Yeah, olfactory, no. Accessory? Optic, no.

01:41:16 Dr Mike

Yeah, optic is thalamus. Yeah, thalamus. Accessory?

01:41:22 Dr Matt

Which one? Which part? Yeah, spinal accessory. Spinal is spinal cord.

01:41:27 Dr Mike

Yeah, I thought so. Okay. So no to those ones. But optic, oculomotor, trochlear, trigeminal, abducens, facial, vestibular, cochlear, glossopharyngeal, vagus and hyperglossal, all their cranial nerves sit within either the midbrain pons or the medulla. And this is important because a lot of these cranial nerves, they innovate the head and neck, which means they allow for us to feel sensory information about the head and neck, but also motor output to the head and neck for us to engage with the environment of the head and neck.

01:41:58 Dr Matt

And so can we go through some of these reflexes? Are we going top to bottom? Partitioned still?

01:42:07 Dr Mike

Yeah. The first thing I think is important to say is that the optic nerve, it goes into the thalamus and so it's not part of the brain stem, but part of the reflexes of the visual system are involving the brain stem because of the motor output. Because in the midbrain, which is the top of the brain stem, you've got the oculomotor nerve and the trochlear. Now, oculomotor is obviously really important for changing pupil diameter and moving the eyeball and trochlear is obviously very important for moving the eyeball as well. Sorry, oculomotor is also the main nerve that will move the eye, but then like you said, the visceral function is going to be the pupil. Yes. So there's two reflexes, the accommodation reflex and the pupillary light reflex, both of which when you shine a light into the eye or get the eye to move, obviously you need sensory information coming into the eye. That's the optic nerve coming into the thalamus, but the output is going to be oculomotor and this is coming out of the midbrain. So this reflex which occurs with optic in, oculomotor out, it's bypassing the brain cortex itself, right? Hence why it's a reflex. This is a brain stem specific reflex. Accommodation is very important for you to be able to focus on something and pupillary light reflex. And look in. Yes. And pupillary light reflex is important for you to be able to limit the amount of photons

01:43:40 Dr Matt

that are entering your visual system. And additional to that, you have a few other reflexes which are in that region, which are going to be to the colliculi, so the superior colliculi, inferior colliculi. And so this would be if you had a large visual object moving towards you, your eyes would

01:44:00 Dr Mike

move towards that. Yes, reflexively.

01:44:03 Dr Matt

And then you have the same with an auditory visual reflex, which is the inferior colliculi, which is brain stem. Also this is in the midbrain.

01:44:12 Dr Mike

And that would be if there's a loud bang or explosion or something, you look towards it. Yes, very good. Some people can also have some problems, not necessarily problems, but what's the name of the, I don't want to call it a disorder, but phenomenon where certain sensory information crosses over? Synesthesia, right? Okay. So some people when they hear loud noises, they see bright lights. That's a very common type of synesthesia. And that's going to be happening in the brain stem and it's a cross connectivity between the visual system and the auditory system. So that they're mixing up signals opposed to the integration and the perception of it? Great question. Don't know. I'll have to look more into it. We should do an episode on synesthesia. That'll be super cool. The other thing about the midbrain is it, remember I was talking about the basal nuclei? Oh, yeah. So a lot of the dopamine producing neurons project from the midbrain. So people with Parkinson's disease, a lot of the dopamine neuronal cell death actually in the midbrain and they've got very long dopaminergic projections that go to the nuclear of the basal nuclei. Right.

01:45:23 Dr Matt

And then play an important role. So does that mean in Parkinson's disease, it's all from the substantia nigra as the

01:45:28 Dr Mike

issue? Exactly. Which we didn't say that's in the midbrain. Substantia nigra. Yes. So the definition of Parkinson's disease is neuronal cell death of neurons in the, of dopaminergic producing neurons in the substantia nigra, which obviously movement, but also reward and motivation. Okay. So there's, there's, so the dopamine produced there are involved in reward and motivation. So again, midbrain.

01:45:50 Dr Matt

Then when we go to the pond, are you done with midbrain? Yeah, I think it's just important to state that the whole brainstem is like a conduit. So things are going up from the body up into the higher brain centers and things are going down from the brain down to the body, but also out to the cerebellum or back from the cerebellum back into other parts. So it is a conduit of things going up and down and across. Very true.

01:46:14 Dr Mike

Yeah. Good point. The pons, we've got other reflexes here. So here in the pons, we've got the trigeminal nerve going in and out. So in and out because in sensory out motor, it's a mixed nerve. And so you can have like a jaw jerk reflex, which is pretty much just trigeminal nerve all the way through sensory trigeminal sensory trigeminal motor. This is where when you open your jaw too far and you stretch the muscles and tendons of the jaw, it reflexively closes the jaw, which is really important with chewing. Right. Okay. Which obviously I don't think you have because you chew like a camel. I don't chew. No. So that's a jaw jerk reflex. The corneal blink reflex. So if I were to rub the white parts of your eye with like a cotton bud or a metal shard, both eyes should blink. Right.

01:47:05 Dr Matt

Both eyes should close. And that's so trigeminal out facial in. Yeah. Yeah. Trigeminal in facial out. I'm sorry. When I say out, I mean towards the brain.

01:47:18 Dr Mike

So trigeminals, the sensory picking it up and facial is the one that's allowing the blink. And then you've got the tensor, temp, the tympani and stapedius reflex, which is when you hear a loud noise, you want to limit any more loud noise coming into damage your ears. So these particular structures sort of close off the ear to limit sound coming in.

01:47:40 Dr Matt

Just the way the conduction moves through the bones of the ear.

01:47:43 Dr Mike

Yeah. And it does this through again, sensory being vestibular cochlea and the motor out being trigeminal on facial nerve. Then from the pons, we move down and we're in the medulla. And down here, we've got cranial nerves like the vestibular cochlea, facial nerve, glossopharyngeal, vagus and hypoglossal. And here's two really important reflexes is the swallowing and gag reflex and the coughing reflex and both are controlled by the glossopharyngeal nerve and the vagus nerve, both in and out. Both are involved in some degree in, both are involved in some degree out.

01:48:22 Dr Matt

Yep. And then in these regions, which we alluded to earlier, would be very important functions, homeostatic functions like the breathing centers. So the pons has some, medulla has some and then the cardiovascular center, which is going

01:48:35 Dr Mike

to be for heart blood pressure is going to be in the medulla. And another important thing about the medulla is that this is often where signals decussate. So like we were alluded to very early on in the podcast about seven hours ago, that information coming from the right hand side of the brain goes to the left hand side of the body and information coming from the left hand side of the body goes to the right hand side of the brain and vice versa. Most of this crossing happens at the medulla. Both motor and sensory. Both motor and sensory. So that's an important point. Depending on what sensory it is though, right? Yes. Like head and neck you're referring to.

01:49:12 Dr Matt

No, I mean like pain, temperature versus. Oh, good point. Yeah. Because that happens, that crosses lower down. Yes.

01:49:20 Dr Mike

At the level it enters basically for pain and temperature. And I don't want to go into Brown and Cicade syndrome. I'd set aside three hours after this to go through it. Fair enough. So the last thing I want to talk about with the brainstem is that there's a whole group of like columns of nuclei that sit deep within the brainstem called the reticular formation. And the reticular formation is really important for circadian rhythm, sleep-wake cycles, and for us knowing or being able to control what information sort of gets projected a little bit higher, like you were saying with the thalamus. So firstly, sleep-wake cycles and circadian rhythm. It basically has neurons that have a clock associated with them. So you know when it's time to go to bed, time to wake up, it's going to be informed by higher levels of the brain associated with looking at photons. So seeing light, not seeing light, melatonin. So there's a whole huge conversation that's had with the reticular formation and other areas of the brain. It's very important in the pain processing pathways. So when you wake up in the middle of the night, go to the bathroom, stub your toe. So if you listen to our last pain podcast, you stub your toe, you've got the sharp A delta fibres and you go, oh, that hurt. Then you've got the dull aching C fibres. Those dull aching C fibres talk to the reticular formation and say, hey, you hurt yourself, stay awake. So it just increases your awareness of that stimuli. That's right. Exactly. In conjunction with that awareness, the reticular formation plays a role when if you take some sort of drugs that are hallucinogenics. And so if, for example, I thought I saw a pink elephant in the corner of the room, I would know there's no pink elephant in the corner of the room. In actual fact, I wouldn't see a pink elephant in the corner of the room because the reticular formation plays a role in not letting me see these made up things. But hallucinogenics can inhibit that process. And that's one of the reasons why you might, again, see a pink elephant in the corner of the room, because your imagination might construct that and it doesn't stop it. Right. So again, is that a filter as well? In that sense, yeah. Okay. All right. So that's the reticular formation. One thing we didn't talk about that I would like to talk about, and we should have spoken about it a while ago, is we said we've got two hemispheres of the brain and they're separate. They don't talk to each other, but they do.

01:52:01 Dr Matt

We didn't talk about how… We alluded to it. We were talking about the white matter tracks and this is an important white matter track that allows the two hemispheres to communicate.

01:52:10 Dr Mike

Yes. It's important that both hemispheres of the brain do communicate with one another. They're not separate and don't communicate. The other thing is there's all this talk about, you know, oh, I'm left brained, I'm right brained. That's all ridiculous as well. So no one's left brained or right brained. You're both brained. You may have things lateralized, like language, for example, might be more predominantly in your left hemisphere, but it doesn't mean that the right hemisphere is not involved in language whatsoever. It just means it's more predominantly involved. Some people can have language in the right hemisphere and not the left, but it doesn't mean you're left brained or right brained. But there is a communication process that connects the two. And like you said, they're white matter tracks called the…

01:52:55 Dr Matt

Corpus. Yep. Body. Callosum.

01:52:59 Dr Mike

Callus. Tough. Right. So the tough body. It's just thick white matter tracks that connect one hemisphere to the other. Your right side of your brain knows what your left hand side of the brain is doing and vice versa.

01:53:11 Dr Matt

So we're going to go back to another episode of lobotomies gone wrong. Let's finish with this.

01:53:17 Dr Mike

Or callosiums gone wrong. Can we finish with the callosotomy and we'll finish up there? Who did this? No idea. But well, there was a researcher called Michael Giesiniger, and he took people who had corpus callosomies. So they cut the corpus callosum. Now, why would somebody have their corpus callosum cut? Epilepsy. You can have intractable global epilepsy in which… Epilepsy is a misfiring of neurons. So usually when one fires off, a whole barrage of neurons fire off and it spreads across the brain. You can have generalized grand mal seizures where you're convulsing on the floor. These obviously aren't great. And they thought, well, the whole point is these neurons are not being limited to the way they fire off. What if we were to cut the connection between the left and right hemispheres? It does this limit these people's seizures? Yes, it did. Great. But what it also did was stop the conversation between the left and right hemispheres. And so what developed in some individuals, not all individuals who had a corpus callosotomy, was that they in a way developed… Two worlds? Yeah, two separate independent modes of consciousness. One that they were aware of, one that they weren't aware of. And so what happened was things like they would go shopping and they'll be pushing the shopping cart and their left hand would be reaching for the Coco Pops while the right hand is reaching for the rice bubbles. And it was competing. Same thing with getting their clothes on. One hand would be putting a shirt on while the other hand's taking that shirt off. Both hemispheres made separate decisions as to what they wanted happening. And you might be thinking, but wouldn't you be aware of both? Well, here's the thing. Because your ability to know what you want to do stems from language, often the decision that's made by your consciousness must project to the language area for you to make sense of what needs to be performed. And so that's often in the left hemisphere. And if the right hemisphere can't project it to the left hemisphere, then you're unaware of what's happening in the right. And so Michael Gezinger, a neuroscientist, did these experiments to highlight those differences and got these people with the corpus callosotomies to look at different things. Now, if something's in your left field of view, it goes to your right hemisphere. Something's in your right field of view, it goes to your left hemisphere. And like I said, language is often in your left hemisphere. And if you want to talk about something that you're consciously aware of, it needs to go to the left hemisphere. So for example, they would show a picture of a duck in the right hemisphere, sorry, the right field of view, and that goes straight to the left hemisphere. And he says, what did you see? And you go, I saw a duck. Now, if you projected that duck to the left hemisphere, the left field of view, it will go to the right hemisphere. And it said, what do you see? Because I didn't see anything. Now you did, but you weren't aware of it because the right hemisphere couldn't throw it to the left to go to the area where you made sense of what you saw. So you didn't see a duck. You didn't see it. You did. But your consciousness didn't allow for you to say that you saw it. Right. So you basically had no idea you saw a duck until Dr. Gazziniga or Professor Gazziniga gave you a pen in your left hand, which is controlled by that right hemisphere that saw the duck. And he said, well, if you didn't see what you saw, can you draw? And he said, I didn't see anything, but sure. I'll see if I can draw what I didn't see. And they drew a duck. Amazing. Wow. Yeah. So that's called the split brain experiment. And I suggest all of you to now go Google the split brain experiment. That's awesome, isn't it? And that, my friend, is a great way to finish on how amazing the brain is, I think. That was nearly a two hour episode, probably our longest episode so far on the brain.

01:57:10 Dr Matt

We will focus on each individual part. On distinct regions and we will go into more depth specifically on each one of those.

01:57:18 Dr Mike

Agreed. We're going to miss out on, we should probably skip some listener mail today because of the length of today's episode. What do you think? And just double up on the next episode.

01:57:27 Dr Matt

I want a couple. You want to read one?

01:57:29 Dr Mike

I'm glad you actually remind me. Okay. All right. So good one. Okay. So Matt's going to read one or two listener mails. We really do love it when you send us emails. Please send it to, go to our website. Is it drmatanddoctormike.com.au or drmatdoctormike.com.au? I think it's drmatanddoctormike. So go to drmatanddoctormike.com.au. I'm typing it in right now. Drmatanddoctormike. Yeah. No, it's… Go to drmatanddoctormike.com.au. No and. Drmatanddoctormike.com.au. Send us an email or you can go straight to gubiosciences.gmail.com.

01:58:08 Dr Matt

Matt, throw out a question or a comment. This was from Welland. They just said that… Where's Welland from? Uganda. Cool. They said, thank you for being using your videos, ANP and biochemistry for my bachelor's degree and much appreciated. Thank you so much. That's a nice shout out. Love it. Then there's one from Vivian. Vivian is suggesting a topic. Where's Vivian from? Switzerland. Awesome. Second year medical student in Switzerland. I'm wondering if you could make an episode on the female reproductive system.

01:58:39 Dr Mike

Oh, we did the male, but we didn't do the female, did we? Yes, Vivian, we shall. She said, we, not we, her, loves the podcast. Thank you, Vivian.

01:58:50 Dr Matt

That's awesome. That's the two.

01:58:52 Dr Mike

That's a mailbag. Awesome. So we do have more. So we'll save them for later. We'll save them for our next episode. Please send us emails. You can contact us on social media, Dr. Mike Todorovic on all platforms basically. Subscribe to our YouTube channel and give us a five star rating and tell us how much you love us. And if you don't love us, well, then why have you listened to two hours of this episode? That's right. Matty, thank you, my friend. And if you want to watch this as a video, go to YouTube. Enjoy the editing, Michael. See you later.