BRAIN SCIENCE PODCAST

With Ginger Campbell, MD

Episode #26

Interview with Psychiatrist and Author, Norman Doidge, MD

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INTRODUCTION

This is the *Brain Science Podcast* – the podcast for everyone who has a brain – and I'm your host Dr. Ginger Campbell. On the *Brain Science Podcast* we explore how recent discoveries in neuroscience are unraveling the mysteries of how our brains make us who we are. For more information including Show Notes, links to previous episodes, and information about how to subscribe please go to the website brainsciencepodcast.com. We also have a Discussion Forum at brainscienceforum.com, and you can send me email at docartemis@gmail.com.

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"I consider this to be—you know, standing back with my experience, both clinically and interest in the brain in general—to be the most important change in our understanding of the brain in 400 years."

GC: This is Episode 26 of the *Brain Science Podcast*, and that was Dr. Norman Doidge, today's guest. Dr. Doidge is the author of, *The Brain That Changes Itself: Stories of Personal Triumph from the Frontiers of Brain Science*. In that quote Dr. Doidge is talking about the discovery of neuroplasticity. In the last year that I've been doing the *Brain Science Podcast* I have found neuroplasticity to be the single most exciting discovery that I have been reading about.

In this interview Dr. Doidge and I talk a little bit about his book. He shares some historical perspective with us, and he was especially interested in talking about what he saw as the obstacles for people recognizing neuroplasticity. We also talked about the work of several of the scientists that were discussed in his book.

If you're new to the *Brain Science Podcast* you might want to listen to Episode 10, which was the main episode on neuroplasticity that I've had so far. Let's get on into the interview.

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INTERVIEW

GC: I want to welcome Dr. Doidge to the *Brain Science Podcast*. Dr. Doidge, thank you so much for being on my show today.

ND: Thanks for having me.

GC: Before we start, Dr. Doidge, would you like to tell us a little bit about yourself and how you got interested in the brain?

ND: Well, the brain is in many respects the most interesting topic, being the command and control center of human beings, so I've been interested in it for years. I studied philosophy before I went into medicine, and I went into medicine with the intention of becoming a psychiatrist, and was just fascinated by the brain from a pretty early age.

GC: And I get the impression from your book that Dr. Eric Kandel inspired you to study psychiatry. I've actually talked about several of Dr. Kandel's books on this podcast. Is there anything you can tell us about him?

ND: I didn't work closely with him, but I did go to Columbia University because of a paper a psychoanalyst had sent me by Kandel, which was a beautiful paper that was explaining his work, and it was talking about how anxiety develops. And it went all the way from his molecular research up to understanding Freud's notion of what was called 'signal anxiety' by Freud. And I realized that Columbia was a place where the biologists and the people who were interested in the mind and psychoanalysis and mental conflict were working together in a respectful way. And so, this was where I wanted to study.

Kandel himself had a very interesting history. He was born in Vienna. His family fled the Nazis when they invaded, and he quickly fell into a circle of other psychoanalysts who fled the Nazis, and wanted himself to become a psychoanalyst and a psychiatrist. And he did become a psychiatrist. But he was a very, very promising lab researcher, and a few analysts—one of them named Mortimer Ostow—said, 'Look, therapy involves learning and changing of patterns, and we really have to know more about how it works at a cellular level.' And they encouraged him to study lab research. And so, he did.

But he never lost sight of the original goal, which was to understand how brain and mind interact. And one of the things that he worked on was something that Freud had proposed. You know the core law of neuroplasticity—sometimes articulated as 'neurons that fire together wire together'—was actually originally articulated by Sigmund Freud in the 1880's and the 1890's. He called it the Law of Association by Simultaneity, and he argued that when two events happen in the mind simultaneously they get associated at the neuronal level; that the connections between nerve cells are strengthened.

And that's basically the articulation of neurons that fire together wire together—which is often called Hebbian plasticity, after Donald Hebb, an American who came to Canada and articulated the same law about 60 years after Freud. So, basically there was this stream of psychoanalysis that was very, very open to plasticity. It's important to remember that Freud was a neurologist and he was a basic neuroscience researcher before he invented psychoanalysis. And he shifted because he felt that the neurology wasn't yet ripe to help explain mental processes.

But he was quite a visionary in articulating this law. And anyone who's ever heard of free association, where the analyst asks the patient to say everything that comes to mind, is actually in fact tapping into an aspect of Freud's thought that had to do with neurons that fire together wire together. The reason it was believed that saying whatever came into your mind might be helpful is it was assumed that events that happened earlier would be wired in the neuronal system and you would be able to gain access to them if you tried not to direct your thought.

So, I went to Columbia and was very, very pleased with the way in which biology and the study of the mind were integrated.

GC: It seemed to me when I was reading Dr. Kandel's autobiography that his story was almost the mirror image of Freud's. Freud started out in the basic sciences and went into psychoanalysis partly because the science wasn't ready yet. And Kandel was going to be a psychoanalyst, but the science had just reached a critical juncture where it could make progress. And it's almost like Kandel had the career you sort of imagine that Freud wanted.

ND: I think that is actually fair to say. But just to go back, one of the reasons we're all so shocked and pleasantly surprised to discover the brain is plastic goes all the way back to Descartes, who for all sorts of reasons—including some political reasons—divided us into mind and brain. And this is really very important for anyone who's interested in understanding brain debates: that with the rise of Galileo, Galileo basically began to explain things, that were explained by the church, by mechanical laws of motion. You know, he explained that the movements of the planets were caused by the mechanical laws of physics.

And scientists were so impressed by him that they began to try to explain the organs of the body mechanically. The first great accomplishment there in the Western world was William Harvey's explanation that the heart was like a pump and the blood vessels had valves, and this kind of thing. And then Descartes came along and portrayed a picture of the brain as very much like a pump, so that in the famous reflex that he described, you tapped on your knee, fluid goes up these vessels to the brain, and then bounces back, and then you contract a muscle, and you have a reflex movement.

But Descartes basically argued that we were divided into a mental substance, which worked by laws that had more to do with logic or laws of how emotions work, and the brain, which was this mechanical machine. And for decades, really, scientists began to assume that brain and mind were disconnected. Descartes had created what people call Cartesian dualism, and there was an abyss. We always knew the mind could influence the body to move, but we didn't know how; if they worked by different laws.

And so all of human knowledge became segregated, in a way, between those aspects of knowledge that studied mind and mental procedures and those that studied the brain and the body. And the two groups weren't talking to each other because they thought that they were looking at different things. And to a degree, those who studied the mind were devalued by those who studied objectivity because they thought it was mere subjectivity that was being studied, and unreliable. And those who studied the mind thought that those who studied mere objectivity were missing the essence of what it was to be human.

This great segregation gave rise to all sorts of problems in practice too, because you would have certain people who would practice psychology just studying the mind, and others who would be practicing neurology or aspects of psychiatry who would just be studying the brain. We always knew that the mind could change. And here's the key point. But if the brain was like a machine we never really believed it could change, despite the fact it obviously did grow. The idea was it was a mechanism; it was virtually inanimate.

Every day I hear stories from people who've read my book—and it's happening today as we speak—where someone has a stroke and the doctors come in and they pronounce that this person will never get better; this part of the brain has been damaged, nothing can be done. It obtains today. Or, whenever we talk about someone having certain mental ability as hard-wired, we're using a sophisticated computer-electronic metaphor for the brain as a machine. One of the reasons I got interested in this is I noticed that when patients didn't get better my colleagues fell back on explaining their lack of progress as because their difficulties were hard-wired in, which meant genetically predetermined in the machine.

Let me give you a definition of plasticity. The definition I like to work with is that it simply means that the brain can change its structure and its function depending on what it does. And that means, depending on what we react to when we're sensing and perceiving—that will rewire our brains—depending on the actions that we commit ourselves to, and most intriguingly, depending on what we think and imagine. All of these things can change the structure of the brain,

And one of the things that Kandel did was he showed how when, first of all, very simple animals and snails were learning, that the connections between the brain cells would change in one way or another. So, this plasticity exists at many, many levels. It exists behaviorally, it exists between the departments of the brain, it exists between the cells in the number of connections, and within the cells. And the thing that was great about Kandel is he just marched forward. He found one part of plasticity and then he went to the next, and the next, and the next. And he would learn new things.

And as genetics became better understood he learned about molecular genetics. And he ultimately showed that when learning is done it gets not only under our skin but under the skin of our DNA, and turns certain genes on and certain genes off. So that, for instance, you can change the number of connections between nerve cell A and nerve cell B from 1300 to 2700 or so, within a few hours of repeating an action. So, when we say the brain is plastic we mean it actually turns certain genes on or off to change the structure. So, this is not a trivial matter that we're talking about here, but a remodeling, or resculpting of the brain at many, many levels. Now, I didn't say it's infinitely plastic. It's a system.

And in the book I tell many stories of these different scientists, many of whom were thought of as heretics by their colleagues, or just silly for pursuing the idea that the brain was not a mechanism, but rather a plastic growing thing. What these people—whom I have described as neuroplasticians—have done is to elucidate and clarify the laws of brain plasticity so that we can facilitate it, hasten it, and deal with it in extraordinary situations such as kids with learning disabilities or autism, or strokes, to really remodel the platforms.

So that after there's been damage, in many cases now we understand that we can reorganize the brain, and that people who are born with disabilities can actually, with the proper kinds of training—that I demonstrate in the book—overcome them. I consider this to be—you know, standing back with my experience, both clinically and interest in the brain in general—to be the most important change in our understanding of the brain in 400 years.

GC: I think I agree with you totally about that. So, then I don't have to ask you why you decided to write a book about it.

ND: No. I was just swept away by the idea and I just realized that this was like a Continental Divide, if you will, in neuroscience between much of what had come before and what was coming after.

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GC: We'll get back to Dr. Doidge's interview in just a moment. But, I needed to take a moment to ask you to subscribe to my other podcast, which is called *Books and Ideas*. It's where I have interviews and discussions of topics that don't quite fit into the *Brain Science Podcast*. The most recent episode of *Books and Ideas* was an interview with Dr. Pamela Gay from the Astronomy Cast.

I will have a new episode out next week. And coming up soon I'm going to have an interview with Dr. Steven Novella from *The Skeptics Guide to the Universe*. So, if you're a supporter of the *Brain Science Podcast* I'd really appreciate it if you would go to booksandideas.com or into iTunes, and subscribe to *Books and Ideas*.

Now I'm going to take you back to Dr. Doidge's interview.

ND: What you want to do as a clinician is understand the limits of plasticity, but also the extent of our plasticity. How fast does this process work? And, of course, it's microscopic. One of the key things I try to address early on in the book is if the brain is and has always been plastic, how is it the case that we missed it? And there are several reasons that we missed it. Now, the first one is what I've called the mechanistic bias. It's the power of that paradigm which—once Descartes had persuaded people this was the way to go—the power of it to control all of our thinking.

In the book I deal with why Descartes' idea of the brain as a machine appealed to us. It replaced an earlier, more mystical view of the brain, a more mystical view of the soul that was in some ways very spiritually uplifting, but wasn't particularly helpful if you got a brain disease. It evoked a lot of feeling, as it still does. The word 'soul' is a very powerful word, and I think there's something to it in a way. But when we used that as sort of our sole way, or vessel, for trying to understand the complexity of mental activity, it just didn't lead anywhere in terms of helping people.

The second thing is that there was just a notoriously bad prognosis for people who had undergone brain damage. But as I started to unpack that and go into the literature I found out that there were many, many cases of people who were born with mental disabilities who improved, and people who had had strokes that improved. But because of the mechanistic bias, when people got better from a stroke what the medical literature did was it said that this person really never lost cortical real estate in their stroke; what happened was after the stroke there was chemical disruption of the circuits and a lot of swelling. And if you waited long enough that would pass, and what they were left with when that swelling and disruption was over was what they had always had all along. We now know that that's wrong.

A third reason that we didn't see plasticity was we just lacked the technologies to do it. To see plasticity you have to see microscopic movies of the brain and changes occurring in that way; or, anyway, that is a very compelling way of demonstrating plasticity. And we now know—for instance in one of the treatments I describe where people have strokes—that massive amounts of cortical real estate are wiped out, it's dead, it will never return; and despite that we can see areas around those lesions reorganizing themselves and taking over those lost functions.

Now, the final reason that we didn't see plasticity is extremely important as far as I'm concerned. It's what I consider the greatest insight I had in writing the book. And it's what I call the 'plastic paradox.' And the plastic paradox is this: that brain plasticity itself deceived us, because the plastic brain can give rise to both flexible and rigid behaviors. And this is going to be a very, very important principle clinically, I believe, as people start to appreciate its importance.

The one metaphor I use in the book is that the brain plasticity is like snow on a hill in winter. And because that snow is pliable, if you want to ski down that hill you can take many different paths down that hill. Now, certain things will determine to a degree the path you take—whether there are rocks on one side, where there are trees, where there's sun, and so on. And as you take that path, being human, if you had a good run down the first time you'll say, 'You know I want to do that again.' And you'll favor that path.

And each time you take that path you'll start to develop tracks. And those tracks, as you repeat yourself, will become ruts. And those ruts are the sort of overly rigid behavior our pliable plasticity can give rise to. And we see them clinically in bad habits and the inability to think in different ways than we're accustomed to. Because when we go down that hill and are in those ruts our brain reward systems are engaged, and those are very, very powerful motivators to keep doing what you're doing.

And there are other reasons why we keep doing what we're doing. I mean it becomes explored territory, our anxiety goes down about doing it in a particular way and another way stirs up a lot of other anxiety. These are mental phenomena. So, human beings are notoriously stuck in ruts. And let me just give you one example of how it plays out clinically. When I was writing the book one of the people I met with was Michael Bernstein, who was a surgeon, who was in his 50's. And he was a tennis buff.

GC: Yes, I actually know Dr. Bernstein personally.

ND: Oh, my goodness! Isn't that funny! OK.

GC: I know how much he loves tennis.

ND: OK. Wow! Small world. So, you probably know then that he was an ophthalmologist doing surgery one morning, and he did a number of operations. And that's microsurgery, really, and requires very fine motor skills. And then he was going to—being Dr. Bernstein—reward himself by playing some tennis. And he got onto the court and then he noticed that he couldn't move a whole side of his body. He went to the doctor, he was rushed to the hospital. Here he was in the prime of life and he'd had a devastating stroke.

And he had the usual rehabilitation, which was as I recall about 6 weeks. And then they said, 'OK, basically this is pretty much all you're going to get in terms of getting better. There'll be a little bit of improvement.' And people were generally told once you're six months out—and some people would say a year out—that's what you're going to be. You have to live with it.

Well, he got out, and he certainly was going to be disabled. He was not going to work as a surgeon anymore, that was for sure. And living in Birmingham, Alabama was one of the great neuroplasticians, Dr. Edward Taub, who had pioneered a treatment for stroke. Now, let's go back to the plastic paradox for a second. What Dr. Taub discovered—because he had done some work on monkeys—was that when patients have strokes—let's say it's a left hemisphere stroke, so they've got a weak right hand—what most people start doing is using their left hand. Even if they're righties, they'll start favoring their left hand—it works, the other one doesn't.

And the brain goes into something which is the equivalent of spinal shock. It goes into what we'll call a brain shock right after the stroke and the damage has occurred. And what happens is the person tries to use that weakened hand and it doesn't work. And they learn the hand doesn't work, at a brain level, so they stop using it. And if there's even a flicker of life in the area around it, it's not engaged. In the meantime they use their better hand and they get by. Of course, there are a lot of activities you need two hands for, like doing up your shirt.

Now, what Dr. Taub realized was if you take the good hand and put it in a sling or a cast, and then give them incremental training for the weak hand simultaneously, you can bring that weak hand back. What happens is there's a brain reorganization in the areas around. In a stroke we know from brain scans that, for instance, typically you might wipe out 50% of the cortical real estate in an area. What he's been able to show is that you get cortical real estate for that mental function back.

But it's really, really important not to use your good hand. Because we know that plasticity in the brain is competitive, and so if you use your good hand, that network is like that keen person in the army or in school when the teacher says, 'Well, who'd like to answer this question?' And those established networks just put their hand up and say, 'I'll do it, I'll do it,' all the time. And they leap forward, and they get recognized. Well, you have to inhibit those networks. It's just crucial if you want to be able to learn new things.

Now, I related this to the plastic paradox because those good networks are like the tracks in the snow. They just say, 'Take me, take me. I'm familiar. You know I'll get the job done.' And so, you take them. And it's a use-it-or-lose-it brain, so each time you take them you further weaken any possibility of other networks developing, and you strengthen these networks. And so, you set up a kind of gradient that favors a particular network.

So, Taub discovered this very, very simple way of getting around this. And this kind of approach has been applied to language loss in stroke. You might say, 'Well, how do you put a sling on an aspect of language?' Well, the way you do it is you make rules for how these people are supposed to speak. And there's a card game that's described in the book that was developed by a German group where they're only allowed to use certain words to describe pictures. And basically they've been able to bring people who had been chronically aphasic—chronically unable to speak—back and able to speak.

So, it's really very remarkable, and it's all based on understanding how brain plasticity works. It just turns out that, as long as there is some functioning cortical real estate in the brain somewhere near the area, it can be recruited. And sometimes it seems that it may be recruited in the opposite hemisphere as well, that's a kind of mirror region of that. So, this is a great example of science finding a specimen illness to work on; but the principles that apply to that illness apply to many, many other conditions.

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GC: I know you want to hear more of Dr. Bernstein's story and more about Dr. Taub's work. Before I talked to Dr. Doidge I recorded an interview with Dr. Taub and we talked about Dr. Bernstein. In fact, I talked to Dr. Bernstein personally before that interview to get his permission to talk about his story. I plan to use that interview for Episode 28, so I'm going to save the rest of the story of Dr. Taub and Dr. Bernstein for that episode.

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GC: In your book you focus both on patients and on the scientists that pursued the clues to the existence of plasticity, even when dogma was saying that it was impossible. And obviously we can't talk about all the scientists that are in your book. But I thought that you might want to talk about Paul Bach-y-Rita. Because, didn't he pass away recently?

ND: Alas, he did. He was a really remarkable, sweet man. And he in a way was the first person of his generation to really take plasticity seriously and systematically. And he was a genius—self-effacing. But he himself had this incredible story, which is perhaps worth telling.

And that is that he was interested in everything and read very widely. He went to medical school on a dare because a friend of his father—Pedro Bach-y-Rita, a poet—a friend of Pedro's sort of said, 'Well, yes, you're very good at all these things, but you could never do medicine.' So, he went to medical school on a dare. But he was never totally satisfied with that. He had a very, very research-oriented mind and was incredibly curious.

His brother, George, also went to medical school. And his father, Pedro, when he was in his late 60's had a stroke that was completely devastating. Now, at the time neither of his sons was living with him. He went for rehab, and they called George—who was at the time studying medicine in Mexico—to come and pick his father up. And he was told that, 'Your father,'—who really couldn't move, couldn't speak—'is not going to get any better. You'd better look at a chronic care institution for him.'

And George couldn't accept it and his father, as far as he could tell, couldn't accept it. And George had no preconceived notions about rehabilitation. So, he took him down to Mexico and he said, 'Papa, you learned to walk as a baby by crawling, so we're going to get you crawling.' And he got him down on all fours—kind of supported by a wall, because he could barely support himself—and incrementally he got one hand, then another, moving. And it turns out in the brain, by the way, this whole idea of crawling and cross-crawling is a very, very important way to reboot and reorganize the brain.

And then he got him to lift one hand off the ground while he crawled; so one hand was supporting him on the wall and the other three limbs were on the ground. And the neighbors looked on and thought it was unseemly as to what the son was doing to the poor professor. And gradually he got another hand up. And he basically incrementally got him to walk.

And then Pedro taught himself to type. And first he would sort of raise his whole arm over the typewriter and let the whole thing slam down on it in a very gross movement. And then he would get to the point where he could just raise his fist and it slammed down. And then one finger at a time. And he got that all back and he got his speech back. And he actually went back to teaching.

And seven years after the stroke—so, he was now in his 70's—he was climbing a mountain in Bogota, Columbia, and he had a fatal heart attack. And the body was brought back to San Francisco where Paul was a physician. And, of course, in those days the way you found out how a person died was you ordered an autopsy. So, he ordered that autopsy. And a couple of days later he was called down to the pathologist's lab. And there, spread before him on slides, were slices of his father's brain.

Paul was numbed and revolted and distressed, but he could see the excitement on the pathologist's face. And as he looked at the slides he realized that 97% of the tracts that had been involved in movement were damaged from his father's stroke; and they were still damaged. A light bulb went off, because what he realized was the work that his father, Pedro, had done with his brother, George, must have reorganized the brain. Because the lesion was so devastating, somehow or other the brain worked around it. He had had inklings of plasticity, but this I think launched him into doing much more research.

Paul went on to write some of the first articles on what he called 'late brain plasticity,' 'late recovery,' and then he got involved in showing the plasticity of the human senses. And I had the privilege of—when I was visiting Paul—being in a room with a woman named Cheryl Schiltz, who had had a devastating illness herself. She had had Gentamicin after a routine hysterectomy. Gentamicin is an antibiotic which on occasion can be devastating to the inner ear and the balance system. And one day, after having the Gentamicin, she found she simply couldn't stand. Everything was moving around her she was so dizzy, and she felt like she was perpetually falling.

And this was so bad. Just think of the beginning of the movie, “Vertigo.” I think it was James Stewart, but anyway, the actor is spinning in this whirl, going into this infinite abyss. Well, that was her life always. And people who have this condition call themselves Wobblers. And it’s so devastating if the lights go out in a room—they can somewhat support themselves if they’re holding a wall, or sometimes they can use their eyes to get a sense of up and down, and left and right—but if the lights go off they’ll fall to the floor. And I asked Cheryl at one point, ‘And what happens after you finally fall into the floor? Does the feeling of falling ever go away?’ And she said,’ No, at that point it’s like a trap door opens up in the floor and I just keep falling.’

GC: I think that would drive me crazy.

ND: Well, it does drive people crazy, and many Wobblers actually commit suicide. It’s one of these terrible, terrible afflictions that you don’t hear much about, and people don’t want to hear much about.

That day I went there, and he had developed this device. It had a long history. It involved basically an accelerometer—which is like a kind of a gyroscope that is a machine that can determine orientation, forward/back, left/right, up/down—in a hat. And you put on the hat and the accelerometer sends signals to a computer, which then sends signals back to something that looks like a piece of chewing gum.

And it’s got over a hundred little itty-bitty, teeny-weeny electrodes on it. And you put that thing on your tongue. And the electrical charge is very, very light, so when one goes off it feels like the ping of a champaign bubble. You put it in your mouth and if you bend forward, as I did, you feel this rush of champaign bubbles going forward on your tongue, and if you bend back it goes back, and left and right.

So, she put on this bizarre-looking hat that Paul had invented. And for the first time I saw her have a state of calm on her face. And she lifted one hand off the table that she was using to support herself; and then a second. And then she just stood there. It looked like someone who was meditating and in a state of bliss. And she'd had that hat on for about 20 minutes.

So, that was miraculous—I use the word 'miraculous' ironically, because it's miraculous if you didn't believe in the plasticity of the brain. Because what we saw was happening in her brain was her balance organ was damaged and no signals were therefore going to the balance system, so there was no way of getting to it and it would begin to degrade and become noisy and chaotic. Which is why she was having these difficulties.

Here he was feeding information about position in through her tongue and somehow or other it was making its way through her brain from her somatosensory—her feeling sense—back to the balance sense part of the brain. Somehow or other new pathways were being used. That was a sign of plasticity. So, she had this thing on for 20 minutes.

The second miracle was the following: when she took the hat off she was still able to stand. She had that peaceful look on her face. There was a residual effect that had lasted. And that effect that time lasted for over three hours. So, she came over to Paul and gave him a hug, she gave me a hug, and then she started dancing with Paul, and she was leading the dancing. And then she was horsing around and walking on the curb one foot in front of the other, and jumping. She had restored her balance system with that little training session.

And over the course of the next year she started wearing that and training her brain. And now she no longer needs to wear the hat. She has developed new neuronal networks—completely new neuronal networks—and she no longer considers herself a Wobbler. So, that is the second miracle, and that's really remarkable that the brain can actually train itself. It wants the input, if you will; it wants to be working, it wants to be learning, if we can only figure out how to get it the proper input.

And Paul Bach-y-Rita used that same kind of approach to help people who had been congenitally blind learn to see through their tongues. As early as 1968 there was this bizarre-looking dentist's chair that he would put blind people in, and it had vibrating, sort of stimulators on the back that were giving information that came from a camera. And they would move this big, clunky old 1960's television camera around.

And they learned to recognize the supermodel Twiggy, and they could actually tell perspective. They could say, 'Oh, you just moved the telephone in front of the vase. And there's Mary; she's wearing her hair down today.' And if you threw a ball at the camera they ducked. So, he was basically doing another piece of what he called sensory substitution. Anyway, a very, very remarkable man, an innovator, and a really great American.

GC: They have that version now for the tongue for vision, right?

ND: Yes, they do. And it's all shrunk down so that basically, instead of that big dentist's chair, you have that piece of chewing gum that you wear on your tongue. And cameras now are very small, so it can be in a pair of eyeglasses. And the computer part is like a big iPod now. Everything is shrunk down.

GC: Do they know what part of the brain, once the person gets to where they can interpret those – ?

ND: Yes, we do know. There were studies that were done in Canada that show that people who use this device to see are actually processing the input in the visual cortex. So, again, it's one of these things where it's coming in through the touch cortex, which is much closer to the front of the brain, and somehow or other there are these pathways that are reawakened, or developed in the brain to the back of the visual cortex.

His theory was that – you know it's very, very important. This is a point that Gerald Edelman makes. It's really important to understand the numbers of possible connections in the brain. I mean it's a staggering number of connections. There's so much redundancy in the brain. One of the very early experiments that he was involved with was a chance discovery. He was in Germany at the time and they were putting microelectrodes into the brains of cats, and they were studying the visual system, as I recall.

Because of Descartes' notion of the brain as like a machine, he saw it as a machine with parts, and each part was in one location of the machine and performed one function. And this was very modular model of the brain. And there's something to it, but the problem is it's not the whole story, and it's too incomplete, and it's too rigid a picture.

But they were basically sticking electrodes into the visual cortex of the cat to try to understand how it was working—which was a very big thing to do in the 60's. Major discoveries were being made at the time as to how vision works. And one day while the cat was sitting there with the electrode in its visual cortex, somebody touched the cat, and they noticed that the electrode in the visual cortex fired. And then they noticed that if there were sounds that electrode fired. And what he realized was that the cortex of mammals was polysensory. Even though we were talking about it as the visual cortex, in fact it was getting connections from all over the place.

Around that time Vernon Mountcastle had discovered the structure of the human cortex was a six-layer structure. That's, again, the thin outer layer of the brain where a lot of perception and higher-level thought occurs. And, of course, all these areas are connected. But what Paul Bach-y-Rita realized was the fact that it was so homogenous meant that areas of cortex that we thought were, for instance, devoted just to vision might be able to also process other things. There is much more homogeneity, and that's consistent with the idea that the brain is plastic, and it's always adapting and learning to process the input that you give it.

[music]

ND: A child might think if you're processing sound in part of the temporal lobe that somehow or other there are sounds in the brain, or that there are pictures in the brain in the visual cortex. But there's nothing of the kind, of course. What happens is all that the brain has in it in terms of signals is rhythmical pulses of electrical patterns. Right? And what the brain does is it learns how to interpret these patterns. And so, if these patterns are coming in from one sense or another, it doesn't really matter. The sense organ—the eye—is just, according to Bach-y-Rita, a data port that basically picks up various rhythmical patterns which it translates into electrical signals.

So, you can reroute these signals throughout the brain. And that's exactly what he did. Because, as he used to put it, we see with our brains, not with our eyes. I mean here was a man who said something which sounds very coy, but then he proved it was right by showing you could attach a camera to the tongue or the back of the arm –

By the way, you may say why the tongue; and it's just really simple. The tongue has got a lot of resolution. There are a lot of nerve endings there. And there's no dead skin layer on the tongue the way there is a dead skin layer, for instance, on another part of your body like your arm, or your back. So, it just was very, very sensitive. And he thought as a data port it was exquisite.

GC: And we have to give him credit because he was so far ahead of his time. He wasn't using information we have now. Like we know now that someone who reads Braille who was born blind is using their visual cortex for that, which is another sensory modality. But he didn't have that information when he was doing his work.

ND: No, he didn't. He didn't have that as a fact, although I think that he was the kind of man who was able to dream that might be a possibility.

GC: There are so many great stories in your book. We certainly could talk for hours. There's one question I want to ask you before we close. I don't know if you have anything to say about this, but I've been getting a lot of questions on this particular topic. And it has to do with pain. What do you think about pain and plasticity? It seems like with pain it's a two-edged sword—neuroplasticity.

ND: Well, it can be. There are several kinds of pain. There is acute pain where basically you're burned by something and you feel it suddenly. And in that case there has been damage to, let's say, the fingertip, or the tip of your tongue if you're drinking a hot coffee. And that is reported to the brain. The problem is we can also damage not only our tissues, like our skin, but we can actually damage our pain system. Now, it's a nervous system, and when it gets damaged the amount of pain it reports is not proportional to the actual damage.

These are called central neuropathic pains. They often show up as chronic pain. And for years people said, 'Well, there's nothing wrong with your hand, so you can't have pain.' But there could be something wrong with your pain system. It got dysregulated. And if it keeps firing it's like anything else—neurons that fire together wire together—you can develop all sorts of kinds of hypersensitivity syndromes. And of course this is like something out of Dante's *Inferno* where a person is just suffering constantly, and then they can't sleep properly, and their emotional and anxiety systems and their vigilance systems get dysregulated.

And so, it's a terrible thing. And it's a sign of plasticity gone awry. Or, I would say it's gone awry. I mean it's not bad plasticity. Plasticity is the operating system of the brain. When we like its results we say, 'Isn't plasticity wonderful.' When we don't like its results—because we're basically addicted to something, or we have a bad habit, or we have chronic pain—suddenly we're afraid of it. And perhaps we should be.

I tell one story; one of the great medical mysteries for many years was the phantom limb. It was named that in the Civil War when so many soldiers had amputations to prevent them from developing gangrene, and then they had these new phantoms that were painful. Whereas you go forward to World War II there were all kinds of phantoms or pains, not just phantom limbs. Men picking up hand grenades that they're trying to throw away from their buddies to protect them have them explode in their hands, and all of the pain of that moment of explosion is something that they feel chronically. It's just a terrible, terrible torment. And that's because it gets into the nervous system and it's repeating over and over again.

And I tell the story of VS Ramachandran, an extraordinary neurologist, who developed a very unusual mirror device to basically eradicate both the phantom limb and the pain that went with it, by fooling the brain. Here's a typical phantom limb story. A person has a mangled arm and the doctors aren't immediately sure what to do with it. They might put it in a sling or a cast because the bones have been broken as well, and they keep observing it. So, it's painful and it's frozen in place.

Then they finally decide to amputate, and what they find is that the person is left with a sense that they have a limb that's frozen. And just nobody put this together before Ramachandran, to my knowledge—that the reason it felt frozen was because it was frozen in position in a cast just before it was cut off, and once the limb is actually cut off there's no subsequent movement to tell the brain that the limb is actually not frozen. It's like the brain just sort of takes a snapshot before the person gets an anesthetic to go under to have their limb cut off, and they're stuck with the pain and the lack of movement.

He basically discovered that one of the reasons people's phantoms are triggered—because sometimes they're on and sometimes they're off—is it turns out that in the brain map, the part of the brain that maps, let's say for touch and movement of an arm, is very, very close to the part of the brain that maps for the face. And because there is no input coming in to that cortical real estate from the arm, and because plasticity is competitive, the map for the face begins to expand into the map for the arm. And there are little bits of cross-wiring that occur. And so, what happens is when a person smiles, or pouts, or chews, or something, the facial map is activated, but it's in the former region of the arm map. And the person subjectively experiences the arm as moving, but in fact what's happening is their face is moving.

And he discovered this because he had a patient who had an unscratchable itch in his phantom arm. And he was trying to understand how it worked, and touched all of their body. Basically one day the man discovered that if he scratched part of his cheek, the itchy phantom went away. So, various versions of Ramachandran's mirror therapy have now been used, not just to treat phantom limbs but one of the most frightening chronic pain syndromes, reflex sympathetic dystrophy, where you have pain, not in a phantom limb but in a real limb. And they have been able to make some real progress rewiring the brain using mirrors to trick the brain.

So, some progress is already being made on dealing with chronic pain, including even some indications we might be able to prevent certain kinds of chronic pain. If you think about it, phantom limbs sound like a very rare thing. But many people go in for operations and have internal organs removed and are left with chronic pain, and some of that chronic pain may have to do with representations of those internal organs. So, many people actually get phantom pain but they don't understand that it's phantom pain from an organ.

Some doctors who are beginning to understand how plasticity works have started to do the following: instead of giving a patient some kind of analgesic after the operation, one of the things you can try to do is give them the analgesic before the operation in lower levels; so that if the brain does take a snapshot, just before the anesthetic, of the pain the person is feeling before, let's say a finger or a part of the body is cut off, it won't be a snapshot of a finger in pain. This is using neuroplasticity to prevent the development of a pain syndrome.

GC: So, that's a good example of how knowledge of neuroplasticity could affect how we take care of patients. How about you in your practice as a psychiatrist? Is there any key way that it's changed what you do?

ND: Yes. It has had a big effect on me. First of all it's had an effect on my attitude. By understanding the plastic paradox I understand, I believe, that when people are not moving I don't extrapolate backwards and say, well, their brains are hard-wired and not flexible. I start thinking, OK, well there's a learning issue here and they're getting deeper and deeper and deeper into a rut, and I've got to try to find ways—like Taub did for developing slings—to stop that. So, that's one way. There are certain techniques I'm exploring that have to do with plasticity.

But the other thing is for the longest time people felt that the only real therapy was 'biological therapy', which meant drugs. And we now have brain scans that show that effective psychotherapies—and we have brain scan studies showing this for psychoanalytic psychotherapy, cognitive behavioral therapy, and something called interpersonal therapy, which in some ways is derived from the psychoanalytic interpersonal approach—we have studies showing that these forms of treatment do rewire the brain when they work. This is just breaking down the ridiculous wall that was put up between biology and the mind, and realizing that these interventions are biological interventions in some very, very real way.

Now, we also know that antidepressants when they're working, and mood stabilizers when they're working—and it should be no surprise—also have some plastic effect. When a person gets depressed in a serious way their hippocampus begins to shrink, and as they get better it begins to enlarge and have new cells. We now know that the hippocampus grows new nerve cells throughout life. This is a great recent discovery. Not all of the brain appears to be as plastic in this respect as the hippocampus. I presume when psychotherapy helps a person get better, or when medications help a person get better, there's plastic change happening there.

So, I'm immersing myself in the understanding of plasticity. It doesn't lead to sudden radical shifts, but there are certain things that do change. I'm much more vigilant, if a person is repeating something over and over again, in letting them know that they're actually making it worse because they're getting deeper and deeper into that rut. But I'd sort of discovered that even before I discovered plasticity. And, of course, the hardest part of therapy is getting them out of those ruts, because they're hooked in perversely to their reward system.

It's just really, really hard for people to change how they're thinking, because we don't think of thinking as like snow on a hill in winter, but it really is. And that's why it was so hard for humanity to accept that the brain was plastic, or to go through any paradigm shift. It's just all these connections are made, and the ruts get deep, and they get familiar, and that means so much to us. Unexplored territory just stirs up so much anxiety that we prefer to freeze and stay with what we know. And that's what happens, by the way, even in neurotic conditions.

GC: Well, that's what happens with scientists too. I mean that's what makes the work of the scientists that you describe in your book so remarkable, is that there are so many people who were like Columbus in a way. I mean they were willing to go into that unknown; even when their work was being pooh-poohed by even oftentimes their own mentors.

ND: Yes. And if I may say, they almost all had something in common, I think, that allowed them to do this. You know your typical late 20^{th} century scientist, early 21^{st} century scientist, is trained to be very, very good on a small area. And these people, a number of them came from a philosophical background, and they were interested in these big problems of the mind. But they were somewhat dissatisfied with philosophy's ability to help them resolve these problems. But they were wide readers. They were never really captured by just one point of view simply.

And Paul Bach-y-Rita is a great example. He spoke many languages and he had many, many incarnations as a scientist in many different areas. And so, that was really very helpful. And that's helpful to all of us in our lives. There's so much to learn and our techniques of learning are so powerful that we tend to stay and become experts, if you will. And there's a lot of reward for being an expert—the best in such and such a thing. But these guys were to a degree scientific jacks-of-all-trades, who then, when it was time to become an expert, each chose one window or another, but had a broader background. And I think that's just so important for a scientist.

But, of course it's not just scientists that get stuck in these ruts. Everybody does. And I get stuck in them. And I think that's just part of plasticity. So, being aware of that, always asking yourself the question, am I doing this because it's the best thing to be doing now or am I doing this just because it's what I tend to do in this situation, is very helpful. And that's a subtle thing that goes on, at least in my mind. I think that way more when I'm with patients, when I'm living my life, and I think about it in terms of how I want to live the rest of my life.

So, for instance, in the 1960's Hubble and Wiesel discovered that the brain of infant cats was plastic, but they both believed that after a brief critical period of plasticity it stopped being plastic and all the circuits were in place for the rest of life. And there were big arguments about that. Now, that discovery of infant plasticity was a shot in the arm, nonetheless, to the whole field of child development. Freudians liked it because Freud had always said that the early years of life were extremely formative. Child developmentmentalists loved it.

If you were educated in that period, when you would think of developmental psychology you thought that meant the psychology of children, or the psychology of children and teenagers. We didn't seriously think of the psychology of late adulthood as having a developmental component; it's deteriorative. I was in that school, too, to a degree, and I once made fun of people who argued to the contrary.

When I was at the Clarke Institute of Psychiatry where I was working at the time, and I saw a poster on the wall called something like, 'Creative Divorce: Divorce is a Developmental Stage.' And I wrote an article that sort of mocked that, and chuckled, and made fun of myself for having missed that phase, and what did I have to do to get it. And I tried to explain that development is a biological concept, that basically our knowledge is that it closes down in young adulthood. That's when we thought plasticity ended, and after that it's just simply a matter of deterioration, and maturity means accepting that.

Now, I was wrong. Not totally wrong; it's not as though the brain doesn't begin to deteriorate. But even as it's deteriorating it's doing plastic changes, and one of the big plastic changes of old age is actually compensating for deterioration. So, older people actually will process certain mental functions—that they worked with in one lobe—in another lobe later in life to deal with the fact that our brains are going down.

But there's still possible development in a major, major way. Not as rapid as in early childhood, but enough to make a big difference in your life. So, I think as we start to appreciate that development, to a certain degree, can go on after 40, we're going to be rethinking how we live our lives. And older people can do some pretty amazing things in their lives.

GC: I think it's pretty exciting. It makes me wish I had more time to learn new things.

ND: Yes, it is. It is exciting. It is exciting and it's reorienting.

GC: Well, I really appreciate you taking so much time to talk to me today. I guess you wanted to tell my listeners where your website is. And if you send me a link I will also put that in my Show Notes.

ND: Sure. Well, you can get to my website easily on Google if you just put 'The Brain That Changes Itself,' and, 'Norman Doidge.' But the actual address is www.normandoidge.com.

GC: Thanks again, Dr. Doidge. I really enjoyed speaking with you.

ND: OK.

[music]

GC: I totally agree with Dr. Doidge that neuroplasticity is the most exciting discovery about the brain; for sure in our lifetime, if not in the last several hundred years. And I hope this interview gave you a taste of the material that's in his book, which is, again, *The Brain That Changes Itself*. Dr. Doidge's writing style is very similar to how he was in his interview. The book is very accessible, even if you don't have any background in science or medicine. It's a great place to start if you're just starting to discover the idea of neuroplasticity.

If you had already read the book that we discussed on Episode 10—which was, *Train Your Mind, Change Your Brain*—you'll probably find quite a bit of overlap between the two. If you asked me which to choose I'd say that the main difference between them is that in *Train Your Mind, Change Your Brain,* Sharon Begley explores some of the evidence about how meditation practice changes the brain, whereas in Dr. Doidge's book, since he's a psychiatrist he talks about the evidence for changes related to psychoanalysis. And he gives some good examples from his own practice relating patients' stories; both the pros and cons of neuroplasticity in terms of treating mental illness. So, choosing kind of depend on what interests you—if you're interested in how meditation changes the brain or if you're interested in things like psychotherapy. But they're both excellent books.

Finally, before I close I want to thank those of you who have gone to the brainsciencepodcast.com website and have contributed. It seems that the subscription option is the one that most people are picking. I really appreciate your support. As always, don't forget that you can let me know what you think by participating in the Brain Science Podcast Discussion Forum at brainscienceforum.com, or you can leave comments at brainsciencepodcast.com, where you can find Show Notes for every episode. And, of course, you can send me email at docartemis@gmail.com.

Thanks for listening. I look forward to talking to you all again soon.

[music]

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