"CHANGING YOUR MIND"
– SHOW 1101



## EPISODE OPEN

ALAN ALDA: This mouse is not only building new muscle; it's growing new brain. And you could too.

ALAN ALDA: (Narration) Find out how running might add new cells to your brain -- and make you smarter. Join us in an experiment that rewires a brain.

ALVARO PASCUAL-LEONE: Wow, this is good!

ALAN ALDA: (Narration) Meet a young woman whose right brain does it all.

ALAN ALDA: That's amazing.

MICHELLE MACK: That's great. I hope this is on tape!

ALAN ALDA: (Narration) Eavesdrop on my dreams -- and peer into my consciousness.

ALAN ALDA: I'm Alan Alda, Join me as Scientific American Frontiers explores novel ways of Changing Your Mind.

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THE SIGHT OF TOUCH

ALAN ALDA: "I've changed my mind." We say and do it every day -- about the gift to buy, the candidate to vote for, the route to take, the dish to order. What we mean of course is that we've made a different choice -- we haven't actually altered the structure of our brains. In fact, the conventional wisdom is that once we are adults, and certainly as we grow older, our minds -- our brains -- remain pretty much fixed and rigid -- certainly our opinions do! Well, guess what: you're going to have to change your mind.

COURTNEY: Hi Michelle, I'm Courtney, one of the dieticians.

MICHELLE GERONIMO: Hi Courtney.

COURTNEY: How are you?

MICHELLE GERONIMO: How are you?

COURTNEY: Good. I just came over to review how the food is going to be set up for the study. Since you're going to be blindfolded.

ALAN ALDA: (Narration) Michelle Geronimo has volunteered to be the subject of an extraordinary experiment. I'm here to lend a little moral support. In a few moments, Michelle is going to lose her sight.

ALAN ALDA: Is this real food?

COURTNEY: These are food models that we use for teaching purposes.

ALAN ALDA: That's a great relief.

MICHELLE GERONIMO: For me too.

ALAN ALDA: Because if that was the real food I wouldn't wear that blindfold if I were you.

ALAN ALDA: (Narration) Neuropsychologist Alvaro Pascual-Leone makes sure Michelle won't peek by tucking a tell-tale snippet of photographic film into the blindfold.

ALAN ALDA: Your last look, huh?

MICHELLE GERONIMO: Yeah, into the darkness.

ALVARO PASCUAL-LEONE: Here we go.

MICHELLE GERONIMO: Here we go.

ALAN ALDA: (Narration) It's now 9 am Monday morning.

ALVARO PASCUAL-LEONE: We're going to start bandaging, OK?

ALAN ALDA: (Narration) Michelle will be totally blind until 3 pm Friday.

AISLING WARD : There are eye pockets, so you can blink.

ALAN ALDA: (Narration) Here's the moral support I mentioned.

ALAN ALDA: Michelle, can you hear me?

MICHELLE GERONIMO: Yes I can.

ALAN ALDA: Hi! ALAN ALDA: (Narration) To get a sense of Michelle's next few days, I'm being blindfolded for the morning. CAROL : Are you both ready to start walking with the cane?

ALAN ALDA: Yeah, who's this, here? Who's that, the cameraman?

PETER: Yes sir.

ALAN ALDA: Well get out of the way!

ALAN ALDA: (Narration) We're headed for the hospital's Clinical Research Center -- and at once my awareness of the surroundings shifts from sight to my other senses.

CAROL : The differences in sound quality.

ALAN ALDA: Sound and temperature.

ALAN ALDA: (Narration) In fact the whole point of the experiment Michelle's about to go through is to see if this shift in sensory input has an impact on her brain -- in particular, on her sense of touch while she learns to read Braille.

ALAN ALDA: D. It feels a little thicker on the top.

LAURIE: It's like a C with another dot.

ALAN ALDA: (Narration) I'm having trouble even feeling the dots, let alone interpreting them as letters.

ALAN ALDA: Eventually you get the shape of it and they just go automatically into your brain as a letter, I guess.

LAURIE: Right.

GIL: "As things turned out, my mother and I were able to leave Cuba together in 1962"

ALAN ALDA: (Narration) But we now need to back up a little in our story, and meet Gil Busch who's been blind from birth. He earns his living as a proof-reader for Braille publications. Information pours into his brain -- principally through the tip of his right index finger -- at an astonishing rate. For years, brain scientists have been fascinated by this skill and have wondered if it involves a change in the way the brain is organized. This little device presents Braille letters to a fingertip for just a few milliseconds.

GIL: E. I. L.O.

ALAN ALDA: (Narration) With Gil's baseline skill established, now comes the dramatic part of the experiment.

ALVARO PASCUAL-LEONE: I'm just taking the magnetic stimulation coil.

ALAN ALDA: (Narration) This coil will deliver a powerful magnetic jolt to Gil's brain, temporarily disabling the region immediately beneath it.

ALVARO PASCUAL-LEONE: We're targeting the back of your brain and in fact the back part we call the visual cortex.

ALAN ALDA: (Narration) The visual cortex handles information from the eyes -- at least in those of us with sight.

ALVARO PASCUAL-LEONE: Does it feel OK?

GIL: It feels fine.

ALAN ALDA: (Narration) Which makes this experiment seem rather odd. Why zap the visual cortex, when what's being tested is a skill involving touch, which is processed in another part of the brain entirely? In fact, this is a recreation of an experiment first done by Alvaro and his colleagues several years ago. Gil's experience today perfectly replicates that experiment.

GIL: They felt very dim, like the dots weren't coming up as well as before.

ALAN ALDA: (Narration) Gil's accuracy declined too. The extraordinary implication is that Gil's visual cortex is involved in reading Braille -- as if his brain has somehow rewired itself to recruit for touch, brain cells most of us use for seeing. And this is the reason for Michelle's abrupt encounter with blindness. The question is: Can her brain also rewire itself to help read Braille -- in her case after just a few days as compared with Gil's lifetime without sight?

MICHELLE GERONIMO: Or king, king, G -- six dots.

ALAN ALDA: (Narration) But for me, three hours of total blindness is enough.

ALAN ALDA: That is bright. Michelle, I can't see!

MICHELLE GERONIMO: That's comforting!

ALAN ALDA: (Narration) Later on that first day of Michelle's blindness, she goes to have her head examined -- in an MRI machine that will take pictures of her brain while different senses are stimulated. To understand the results we need a brief lesson in brain anatomy.

ALAN ALDA: Can you show me the parts of the brain that I use when I'm looking at stuff?

ALVARO PASCUAL-LEONE: Yeah. Let me open up your head.

ALAN ALDA: OK.

ALVARO PASCUAL-LEONE: So basically of course the light would be coming in through here, and it actually travels all the way to the very back of the brain, the occipital cortex, that is the visual cortex.

ALAN ALDA: Back over here.

ALVARO PASCUAL-LEONE: Back over there.

ALAN ALDA: So if that's where I see, where do I feel?

ALVARO PASCUAL-LEONE: Right, so the information from your hand, from your right hand, will come to the left side of your brain, specifically here, to the posterior part of the central sulcus. Information from your left hand will come to the other side, on the right side of the brain.

ALAN ALDA: (Narration) In this day one testing of Michelle's brain, the results were no surprise. When the index finger of her left hand was stimulated, the touch-sensing region on the right side of her brain lit up, just as it would in you or me. But now Michelle settles down for her 100 hours of blindness. A favorite movie doesn't need the picture. There are walks around the hospital corridors. Activities to exercise her sense of touch.

MICHELLE GERONIMO: Happy Valentine's Day.

ALAN ALDA: (Narration) And practice reading Braille -- hours and hours of practice reading Braille. Until finally it's Friday.

CLOCK: 12:39 pm

MICHELLE GERONIMO: 12:39 pm, which means I have 2 hours and 21 minutes left.

ALAN ALDA: (Narration) Michelle's week of total darkness was relieved by one vivid visual hallucination.

MICHELLE GERONIMO: I had an image on my blindfold, on the left side, black and white still shot of a face, looking to the left, really clear, really distinct really odd -- because it was Elvis Presley. And it was Elvis the later years, Elvis with a little more hair and the rhinestone outfit with the white collar.

ALAN ALDA: (Narration) In these last few hours of blindness, Michelle returns to the MRI scanner. This time her brain looks very different. Instead of her touch-sensing region lighting up, now her visual cortex is activated. It's as if, finding itself with nothing better to do, the visual cortex has stepped in to help with a task it's more skilled at than is the touch region -- making sense of symbols. This possibility is strengthened when Michelle is tested as Gil was -- to see if disrupting her visual cortex impairs her ability to read Braille. Her Braille test is a little easier than Gil's -- to identify whether pairs of letters are the same or different. Now Michelle's visual cortex gets 10 minutes under the magnetic coil.

ALVARO PASCUAL-LEONE: OK, we're all done.

RESEARCH ASSISTANT: Michelle, we're going to test your right index finger again.

MICHELLE GERONIMO: OK.

RESEARCH ASSISTANT: Ready?

MICHELLE GERONIMO: Yes. Different. Different.

ALAN ALDA: (Narration) Sure enough, just like Gil, her accuracy drops markedly. For Alvaro, already happy as the results emerge, there's a bonus.

MICHELLE GERONIMO: I found that my fingers have been a little less sensitive, since the TMS testing, the stimulation, to the feel of the characters from the Braille task.

ALVARO PASCUAL-LEONE: That's fabulous. We'll pay you another $500!

MICHELLE GERONIMO: Thank you.

ALVARO PASCUAL-LEONE: That is exactly what we're looking for. We were wondering whether there would be some function related to touch that would be taken over by the visual cortex over the time that you've been blindfolded. And the fact that your fingers feel less sensitive now would suggest that that actually has been the case. Wow! This is good.

ALAN ALDA: (Narration) Alvaro has reason to be excited. Michelle's experience is dramatic confirmation of his hypothesis that the brain can reorganize itself in just a few days, let alone a lifetime.

ALVARO PASCUAL-LEONE: I would say that the brain is like, you know, market economy. There is demand for a certain thing, we activate what it needs to cover that demand. There is no demand for it. We use it for something else. It is just like any good shopkeeper would do: you adjust whatever you offer to people passing by, by virtue of what they are going to need.

MICHELLE GERONIMO: I feel this blindfold has become part of my face.

ALVARO PASCUAL-LEONE: You ready? You want to keep your eyes closed to begin with.

MICHELLE GERONIMO: Oh, geez. Hi. When the blindfold came off I was a bit disoriented and a bit unbalanced. I'd been dependent on hearing to orient myself, and then when the vision came back I found myself off guard and had to take things in a new way now. But now I'm alright.

ALVARO PASCUAL-LEONE: So, we'll ask you to put on a blindfold again -- just for the test -- and do the Braille discrimination.

ALAN ALDA: (Narration) Having her vision restored has in fact had an even more profound effect than Michelle realizes. When her visual cortex is zapped the next morning, her ability to read Braille is unaffected. After just a few hours of working at its usual job, her vision center has apparently found it's much too busy to any longer help out with touch. Michelle's five days of blindness has provided astonishing confirmation of the malleability of the human brain.

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GROW YOUR OWN BRAIN

ALAN ALDA: (Narration) Our next story begins in London, where of all the brains in the world, few have been changed more than the one behind the wheel of a London taxicab. No one can drive a traditional black cab in central London without first demonstrating "the Knowledge" -- a mental map of London's maze-like streets.

INSTRUCTOR: Can you take me from Winfield House, the American Ambassador's residence, to Old Bond Street?

CABBIE: Leave by gate, left down Park Road, bear right Baker Street, through Portman Square, left into Wigmore Street, right Welbeck Street.

ALAN ALDA: (Narration) Scientists recently scanned the brains of 16 volunteer London cabbies, and discovered that they all possessed a larger than normal hippocampus -- the area of the brain used for packaging memories before they're stored. Only months before, an even more astonishing discovery had been made about this same region of the brain.

FRED GAGE: So this is the imaging room.

ALAN ALDA: (Narration) Fred Gage here at the Salk Institute in California led a team that found brand new neurons in the hippocampus of Swedish cancer patients. Before they died of their disease, these patients had volunteered for a study that labeled any newborn cells in their bodies with a bright green dye. This is a slice of brain tissue from the hippocampus.

FRED GAGE: The green corresponds to the molecule that was injected into the blood of the patient 2 years before he died. Which means that the neuron was born when the patient in this case was 62 years old. And at some later point, it became a mature neuron in their brain.

ALAN ALDA: That was clear indication that there were cells dividing in this mature person?

FRED GAGE: Yes, yes.

ALAN ALDA: (Narration) This discovery has set the field of brain science on its head, overturning the long established dogma that once we are adults we only lose brain cells, never gain them.

FRED GAGE: There were not only cells dividing but cells that were becoming neurons in the adult brain.

ALAN ALDA: (Narration) Today research labs all over the world are scrambling to understand the implications of this discovery. The starting point for much of this work was a study of rats done at the University of Illinois. When rats were raised in an environment that's more interesting and challenging than the usual lab cage, their brain cells made many more connections. But there had never been any hint that they also made new neurons. until Fred Gage and his colleagues set up a similar study with mice. Not only did they find new neurons -- once again within the hippocampus -- but mice living a more interesting and active life had more new neurons than did mice sitting around being bored. The mice had running wheels as well as toys in the cage. To find out if simple exercise had anything to do with growing new brain cells, the Salk team gave some mice just a running wheel.

HENRIETTE VAN PRAAG: To our surprise, we found that mice housed just with the running wheel had the same number of newborn brain cells as the enriched environment, suggested that just physical activity, or exercise alone, can generate new brain cells.

ALAN ALDA: (Narration) Having new neurons sounds good. But do they do any good?

HENRIETTE VAN PRAAG: This is his very first time in the pool, he's never been in the pool ever before in his life.

ALAN ALDA: (Narration) Henriette tested her mice for their ability to find a platform hidden just beneath the surface of the milky water.

ALAN ALDA: He doesn't even know there's a platform, huh?

HENRIETTE VAN PRAAG: He doesn't know. He knows nothing.

ALAN ALDA: Has he found it?

HENRIETTE VAN PRAAG: He's found it. But basically he's been lucky. It usually takes two or three days for the mouse to learn this task and seven days of training for it to learn it really well -- for me to put him in the pool and he'll swim to it in one straight line in two or three seconds.

ALAN ALDA: (Narration) Henriette compared the time it took for both the exercised mice and mice housed in standard cages to find the platform.

ALAN ALDA: Do they tend to go around the outside and then start to look for other paths? Woom, he found it.

HENRIETTE VAN PRAAG: It actually turned out very well for the mice on the running wheel because they managed to escape from the water faster, in a shorter amount of time than mice housed in standard conditions. So this suggests that these mice have learned better and that they are smarter.

ALAN ALDA: (Narration) So running mice not only grow more new neurons. They also seem to be benefiting from all that extra brain.

ALAN ALDA: Have you started running?

HENRIETTE VAN PRAAG: I've started and stopped running.

ALAN ALDA: But we all do that! Did you start because of this? And why did you stop?

HENRIETTE VAN PRAAG: I started because of my experimental results and because of looking at my slides with this dramatic increase in new brain cells. But you have to be pretty disciplined to keep it up and keep running every day.

ALAN ALDA: So are you maybe hoping that further experiments will show that you don't actually have to run? Maybe just rocking in the chair would be enough to do it, you know.

HENRIETTE VAN PRAAG: Well, what worried me was that these mice were running twelve hours every night. I wondered how we could even run enough to compare with that. So we did one experiment where we brought down the time of running to four hours every night for five days and we already found a 30% increase in cell division just after the short period of time. So I'm hoping we can bring it down.

ALAN ALDA: To something we can handle. Good. Call me when you find out, OK?

ALAN ALDA: (Narration) The task now is to find out just how running or an enriched environment creates new neurons. Growing cells in a dish outside the brain is one way the Salk researchers are exploring this question. These are brain cells actually dividing under the microscope. The hope is to discover the chemical signals involved, and then find ways to use these chemicals directly to grow new neurons -- perhaps even in the brains of people such as Parkinson's or Alzheimer's patients who have lost neurons to their disease. In the meantime, I'll never think of my own brain in quite the same way again.

ALAN ALDA: There must be in my brain right now a lot of stuff going on, birth and migration of cells. Am I right about that? Should I have a new picture of my brain?

FRED GAGE: I think almost more remarkable than just the fact -- which is remarkable enough -- that there's all this movement and plasticity, that that movement and plasticity and adaptation that's occurring all the time in the brain is regulated by the behavior that you emit as an individual. Our brain controls our behavior, but our behavior can also affect the structure of our brain, which in turn is going to change how we behave.

ALAN ALDA: (Narration) Which brings us back to those London cabbies again. Perhaps the reason for their enlarged hippocampus is that they are adding neurons with all that enrichment they're getting navigating London streets. Now just imagine how much extra brain a cabbie might grow if he ran twelve hours a night!

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TRUE OR FALSE?

ALAN ALDA: (Narration) What I didn't know while I was taking a walk one morning was that I was being set up -- for a demonstration that it's not just our brains that are malleable. So too are a lot of the things we store in them.

DAN SCHACTER: Now we're just going to witness a... simple picnic scene and we want you to pay attention to how often either of the folks gets up and down. So whenever someone gets up and down you just make a mental note of it.

ALAN ALDA: OK.

ALAN ALDA: (Narration) I knew Dan Schacter to be a noted memory researcher. But this picnic was a surprise.

ALAN ALDA: Oh good, I love to watch people eat.

ALAN ALDA: (Narration) Although Dan had told me to keep track of how many times the picnickers stood up, I suspected there was more to this little scene than that. But what? I wasn't to find out for another two days that the picnic was part of a carefully choreographed attempt to implant false memories into my brain - to make me "remember" as real things I'd never seen. At the time it was like trying to keep track of a very bad play while sitting uncomfortably close to the author. After ten bewildering minutes, the picnic - mercifully - came to an end.

ALAN ALDA: Bravo. Very nice, very nice.

DAN SCHACTER: We could have used a little more high drama here and there.

ALAN ALDA: Yeah, but it doesn't lack for slowness.

ALAN ALDA: (Narration) At this point I was politely asked to leave. The scene was played over for a stills photographer. But this time it included things that never happened while I was there. Which meant I also missed Dan Schacter's basic premise: that memories are malleable.

DAN SCHACTER: One of the things that we know about memory is that it's not fixed at the original experience we have. The way we talk about the event later uh... the way we think about it uh... can effect, improve or sometimes change our memory. And photographs are one everyday source of reviewing past experiences that may have a potent effect on memory and we're interested in exactly what that effect is.

ALAN ALDA: (Narration) Two days later I was in Dan Schacter's office at Harvard University, looking at photographs.

DAN SCHACTER: ... is it well cut-out, is it well centered? For each photo I'm gonna ask you for a one to five rating.

ALAN ALDA: Oh... heh heh, part of me is trying to figure out what this is really a test of. I'd have to say, you know, four to four point five. This is a nicely composed picture.

ALAN ALDA: (Narration) I didn't believe this rating ploy for a moment, but graciously played along - even when the photos where of things I knew I hadn't seen.

ALAN ALDA: I take it you don't want me to mention whether or not this is a picture of something that happened or not, because this never happened.

DAN SCHACTER: Right, we're not concerned with that right now. We're just concerned with...

ALAN ALDA:... showing how smart I am.

DAN SCHACTER: Right!

ALAN ALDA: (Narration) In all I looked at about twenty photographs. Finally the moment I'd been anticipating... ... the test.

DAN SCHACTER: ... the fishing pole?

ALAN ALDA: No. ALAN ALDA: (Narration) The question is: did I see these things at the picnic or not?

DAN SCHACTER: Umbrella?

ALAN ALDA: No umbrella, no.

DAN SCHACTER: Potato chips?

ALAN ALDA: No. The potato chips were in the picture. Well, I remember them in the picture but I don't remember them on the site.

ALAN ALDA: (Narration) I was doing fine until...

DAN SCHACTER: Nail file?

ALAN ALDA: Yes I think I remember her filing her nails, although the picture is also vivid in my mind. But I think I remember her filing her nails, too.

DAN SCHACTER: Kite?

ALAN ALDA: No kite. No, there was no kite. There was a kite in the picture but that's it.

DAN SCHACTER: OK. A man's cap.

ALAN ALDA: (Narration) By now it was obvious that Dan was trying to confuse my memory of things I'd seen for real...

ALAN ALDA: I think he wore a cap.

ALAN ALDA: (Narration) ... with things I'd only seen in the photographs.

ALAN ALDA: Well, see... I think he was wearing a cap in the photographs and I think - and I remember when I looked at the photographs - there's something wrong with this picture. I don't think he wore a cap.

DAN SCHACTER: A bottle of water?

ALAN ALDA: Yes, there was a bottle of water.

ALAN ALDA: (Narration) Oh, oh, this would come back to haunt me. DAN SCHACTER: Folding chairs?

ALAN ALDA: No! DAN SCHACTER: No, no way. Pasta?

ALAN ALDA: Yes! You think I could forget pasta? Come on!

DAN SCHACTER: It's over.

ALAN ALDA: That's it?

DAN SCHACTER: That's it. It's out of your system.

ALAN ALDA: So it had nothing to do with how many times they stood up.

DAN SCHACTER: Well, that was just to get you to pay attention to what was going on in front of you.

ALAN ALDA: Yeah, that's why I paid attention to everything else. Now what I'm really interested to know is, were you able to place in my memory things that never occurred in real life?

DAN SCHACTER: Yes.

ALAN ALDA: You did? You did?

DAN SCHACTER: We did. Even though um... even though we... you know, we told you, you knew what the game was. You knew that some of things that we were showing you in the photographs had never happened. Despite that...

ALAN ALDA: This is horrible.

DAN SCHACTER: One was the nail file.

ALAN ALDA: Yeah.

DAN SCHACTER: That was only in the photo.

ALAN ALDA: You know, when I first saw the nail file there was this little uncertainty - was that real or wasn't it - and then a second later, I was... I was sure I'd seen it.

ALAN ALDA: (Narration) In the final tally, of eight things that appeared in the pictures only, I wrongly remembered two as having been at the picnic - the nail file and a bottle of water. The photographs had somehow lodged in my brain right along with my memory of the picnic itself and I couldn't tell which was which. To understand how this can happen means we have to first understand where in the brain memory is located.

ALAN ALDA: Is it possible to point to some place on the brain and say that's where memory is?

DAN SCHACTER: Well, there's no one place - there's no one place I can point and say 'there's your memory of high school graduation and.. and there's your memory for having eaten breakfast yesterday. Instead of being in one place, many of believe that memory is kind of scattered in different parts of the brain.

ALAN ALDA: (Narration) The idea is that memory consists of all the bits and pieces of an experience - the sights, the sounds, the emotions - with each fragment stored in areas of the brain responsible for handling that particular sensation. So sounds are stored in the auditory cortex, sights in the visual cortex and so on. Keeping track of what's where is our old friend the hippocampus, which functions as a sort of index for our memories. Recalling an event means re-assembling all those bits and pieces. It's not like replaying a videotape. It's more like shaking a kaleidoscope. With every shake - every recall - the pieces fall together all over again - sometimes, as in my memory of the picnic, including bits that don't quite belong. Dan Schacter wondered if he could tell the difference between real and false memories by peering into the brain while it was remembering. Twelve people heard word lists like these, and had to remember as many of the words as they could.

ALAN ALDA: Writer... um...

ALAN ALDA: (Narration) What's sneaky about the lists is that while they're each united by a theme, they don't contain the most obvious word...

DAN SCHACTER: Bed, rest, awake, tired, dream, wake, snooze, blanket, doze, slumber, snore, nap, peace, yawn, drowsy.

ALAN ALDA: Sleep, doze, bed...

ALAN ALDA: (Narration) There - right off the bat I said "sleep", but sleep wasn't on the list. Again, I'd been given a false memory.

ALAN ALDA: ... ah, bed...

ALAN ALDA: (Narration) The twelve experimental subjects all got PET scans while doing this test. Recalling both true and false memories mostly involved the same bits of brain, especially the hippocampus - the index region. But while the true memory lit up the auditory cortex, the false memory didn't. So even though the subjects reported hearing the words that weren't there, their brains appear to contain no trace of the sounds of the words.

ALAN ALDA: So in a way you really can look inside somebody's brain and tell whether they're having a true memory or a false memory under certain conditions.

DAN SCHACTER: Under certain conditions. Within this one experimental paradigm group of twelve people we were able to see, ah, some differences between true and false recognition.

ALAN ALDA: (Narration) Dan Schacter emphasizes there's a long way to go before this first faint trace of a false memory could be turned into a practical test that could be used, for instance, in a courtroom. Meanwhile, discovering how easily my memory can be tricked was lesson enough.

ALAN ALDA: What I think this really brings home to me is it's very important to say not 'this is what happened' but 'it seems to me that I remember this is what happened.'

DAN SCHACTER: I think that's a very important lesson.

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WHAT'S IN A DREAM?

ALAN ALDA: (Narration) It's time for me to change my mind -- from the one I use most of the time during the day.

ALAN ALDA: Hello... I sit here?

ALAN ALDA: (Narration) To what turns out to be a much more creative one at night.

JEN HOLMES: OK, he first that we're going to be doing tonight is putting electrodes on so we can measure your electrical activity and know your stages of sleep.

ALAN ALDA: What's that?

JEN HOLMES: It's called calodian, it's very similar to airplane glue. And what this...

ALAN ALDA: (Narration) Airplane glue in my hair... as it turned out only the first of several indignities that lay ahead during my night as a research subject at Harvard University's Sleep Laboratory.

ALAN ALDA: I don't want to rush you, but I'm falling asleep.

JEN HOLMES: Are you really? Good.

ALAN ALDA: (Narration) The study I'm joining is to find out what happens to our minds while we're dreaming.

JEN HOLMES: OK, and that's the last electrode.

ALAN ALDA: (Narration) Like most people, I've always been fascinated by dreams - my own especially. How do our brains come up with that stuff? Even more interesting - why? My night began with a test of the state of my brain. The task is to spot if the second of two words flashed on the screen is a real one. Sometimes the second word seems to be related to the first. When it is, and my brain makes the association, then I'm usually able to decide if the second word is real or fake more quickly. So by measuring my reaction time, the test can tell how good my brain is at making associations.

ALAN ALDA: Bed... bed.

ALAN ALDA: (Narration) The only association I was interested in right then was between bed and sleep - not so easy when you know a stranger is eavesdropping on your brain.

JEN HOLMES: Alan, I need you to lie quietly with your eyes closed. OK, if you could blink five times, slowly...

ALAN ALDA: (Narration) This is to check the electrodes near my eye. They'll be looking out for REM - R.E.M. - the rapid eye movements we all make when we dream.

JEN HOLMES: Great. OK, you're all set. You can go ahead and get comfortable and have a good night's sleep.

ALAN ALDA: (Narration) So if you'll excuse me, I'll leave you in the care of Jen Holmes while I try to sleep with wires pasted on my face and glued to my scalp.

JEN HOLMES: Now he's moving, getting comfortable and you'll typically see some kind of movement when people first start to fall asleep. He's now officially asleep. Our experiment calls for him to do the word association test several times during the night, one of them when he's asleep but not dreaming. That's what's happening now, so I'll go wake him up.

ALAN ALDA: Yep... nope... oh, I'm falling asleep here. I am not checking into this hotel again.

ALAN ALDA: (Narration) Well, after that my night went to pieces. Every time I drifted off and started to dream I'd think, oh good, I have to remember this - and promptly wake myself up. By six in the morning, Jen had been joined by her boss, Bob Stickgold, and it began to look like we weren't going to find out what my brain does when it's dreaming.

ROBERT STICKGOLD: Since about, ah, 2:30 this morning he's been having a hard time sleeping. Uh, he'll go to sleep - he'll sleep for ten of fifteen minute series - you can hear the pens slapping around - he's rolling around in bed now. He's been doing that for hours now.

ALAN ALDA: (Narration) But then, when it was almost too late, I began drifting into a dream.

ROBERT STICKGOLD: If we wake him up right now we've got an eighty-five percent chance - a ninety percent chance - of getting good REM reports. So what we want to do is wait until it gets another burst - there's some more right there, look at these, these are really good eyes movements, these are fast and they're big. So, I think we should go in there now and see what we can get.

ALAN ALDA: I was... uh, being propelled the solar wind but the wind wasn't behind me, I was going toward the sun. And I was flying over Berlin and I remember thinking that this was, uh... called uh... 'Nightgown Over Germany.'

ROBERT STICKGOLD: It's only about six-thirty, it's still early.

ALAN ALDA: Oh, it's still early. Well, let's try it.

ROBERT STICKGOLD: Let's try it. OK. Pleasant dreams.

ALAN ALDA: (Narration) With one dream in the bag, I felt better about trying for another... So that once again I could be awakened for that exciting word association test.

ROBERT STICKGOLD: So, how does it feel to you that you slept?

ALAN ALDA: How did it feel that I slept? I had a worse night of sleep at a truck route in New Zealand.

ROBERT STICKGOLD: Really?

ALAN ALDA: Yeah...

ALAN ALDA: (Narration) By now all I wanted was a little breakfast and the airplane glue out of my hair. But I was also curious, of course, about the tests I'd been taking. What did they have to do with dreaming? Most dream researchers believe that during REM sleep the normal signals to the brain from our bodies are cut off. Instead of receiving inputs from our eyes and ears, the visual and auditory centers are flooded with signals surging up from the more primitive regions of the brain. These signals, the theory goes, are completely random and meaningless. But dreams, of course, seem to make sense - at least at the time.

ALAN ALDA: ... the wonderful part about it was I went out through my nose, see? So then I had all these words I was hearing...

ALAN ALDA: (Narration) So the key question is, where do the stories of our dreams come from? According to Bob Stickgold, we simply make them up as we go along.

ALAN ALDA: I'm a little thick this morning because I... I had this funny night sleep. I still don't quite get how you arrive at the conclusion that something in the brain is supplying story and meaning and uh... uh... a coherence to...to these random images... and not that they're coming up in a more coherent way already.

ROBERT STICKGOLD: If you look at your dream, I mean there you have the start of - gee, it's going to be an out-of-body experience, and first of all it goes out through your nose. I... I'm sorry, it's just hard for me to believe that someone scripted that for you to do. You were just thinking 'out-of-body, how am I going to get out of body, help me somebody how can I get out-of-body' and something in your brains says 'oh your nose.'

ALAN ALDA: (Narration) So during dreaming, our brains are scrambling to make sense of nonsense. Here's where the word tests are revealing - because subjects woken from REM sleep are quicker at making associations between words than when woken from non-REM sleep - or even when they are wide awake during the day. It's as if during REM sleep our brains are primed to put together stories from random images and feelings.

ROBERT STICKGOLD: Our guess is - and it's truly just a guess at this point - is that the brain is just trying to keep up with these random inputs and trying to use everything it knows to make some kind of sense out of it.

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MONASTERY OF THE MIND

ALAN ALDA: (Narration) Cut into the top of a California hill is the creation of a Nobel prizewinner now well into his third scientific career. It's a place he likes to compare to older institutions with a fondness for hilltops.

GERRY EDELMAN: Take a look around and look at this surrounding here, it's like a cloister. So when the architects asked me about the place, I said I want it to be a scientific monastery. I don't want it to be like a church. I want it to be a place where you can contemplate and look ahead 20 years. Now in science, 10 years is about as much as you can try to look ahead. Otherwise you're a crackpot. But we try.

ALAN ALDA: So you have them looking ahead 20?

GERRY EDELMAN: Show a little discretion here!

ALAN ALDA: (Narration) Gerry Edelman has looked beyond the horizon for all his nearly 50 years in science. In 1972 he won the Nobel Prize for Medicine, having succeeded at a task that daunted most biologists at the time -- figuring out the structure of the antibody molecule. He went from that to working on how living things grow and develop. And then he switched fields again, to brain science. Five years ago, he conceived of the Neurosciences Institute, a place that would take on the biggest scientific mystery of all -- understanding the human mind. Which meant I was a little unprepared for my first stop at the Institute -- to visit a modest and very unhuman machine roving around an indoor pen.

ALAN ALDA: What is this little guy doing in here?

GERRY EDELMAN: Well, this little guy, whom we call Darwin, after a very famous biologist and because he's based on a similar principle to that of natural selection that Darwin invented, is a creature or a device that's intended to simulate how the brain and the body work together.

ALAN ALDA: How they work together?

GIULIO TONONI: How they work together. And the idea is something like this. It looks like a robot but it is not a robot.

ALAN ALDA: You mean it hasn't been programmed to do specific actions?

GIULIO TONONI: That's exactly right. There is no computer program telling it go three steps, turn to the right, if you see this, do that. Instead, like an animal, it's born a certain way, has a brain of a certain kind, and when it make errors it corrects the errors until it gets something that satisfies it.

ALAN ALDA: (Narration) Darwin's brain is actually much too be big to be carried around in its body. The brain occupies a supercomputer in the basement, and keeps in touch with its body by radio. When Darwin was born it knew next to nothing, not even that there are two kinds of blocks in its world, one marked with blobs, the other with stripes. But like a newborn, it does have sight -- and a liking for things that taste good.

GIULIO TONONI: There's a gripper in front. The gripper is a little bit like your tongue -- in a peculiar position -- and it will sense electricity and conductance. So when it grabs a block it will get a quote-unquote taste. If the taste is bad it will drop that block and there will be a change in the strength of its nervous connections. Therefore it will learn as it were to stay away from a block with that shape.

ALAN ALDA: (Narration) In Darwin's world, it's the blobby blocks that taste bad, while blocks with stripes taste good. With just this built-in taste preference, Darwin gradually figures out what it needs to do to live the good life. The brain itself is modeled on a mammal's brain, with a visual cortex to receive the camera image and a second specialized area that interprets what it sees. In the computer, simulated neurons form a network with a quarter of a million connections. As Darwin blunders naively around its pen, these neuronal connections begin to become organized. Here are groups of neurons firing together when it sees stripes. Entirely different groups of neurons light up for a blob. These neurons are in turn connected to motor nerves that control Darwin's behavior.

GERRY EDELMAN: And the rule is very simple. Neurons that fire together, wire together. So that when the nerve cells or neurons are strengthened after it gets a reward, that's more likely to make its behavior similar the next time.

ALAN ALDA: (Narration) Darwin's brain is intended as a model for our own -- except that we have trillions upon trillions of possible connections between neurons instead of a mere quarter million. We become who we are through the strengthening of some of these connections-- between neurons that fire together -- and the weakening of others. To Edelman, the brain is the ultimate gooey plastic, capable of near infinite possibilities, molded by its experience into one of them. Even as we watch, Darwin's experience is turning it into a creature that craves stripes and rejects blobs on sight.

ALAN ALDA: Do you hit the reset button every few months and let him be born again to see how he...

GERRY EDELMAN: Oh yes. Since it's very expensive to make 20 of them we generally wipe them clean and start again.

ALAN ALDA: And then you see how he learns with this new life that he has.

GERRY EDELMAN: And each one does it differently.

ALAN ALDA: (Narration) Each one does it differently because its individual experience in its world is different -- the blocks are in different places, and it encounters them in a different order. Each incarnation of Darwin's brain is shaped by its own particular life -- just as our's is. This makes it very different from even the most sophisticated conventional computer.

GERRY EDELMAN: Gerry Edelman If you are going hunting for birds in a swamp on a rainy day and I gave you an Air Force computer that was friendly and spoke English in a teacup, would you take that or would you take a dog?

ALAN ALDA: Right.

GERRY EDELMAN: That's what we're trying to understand. How does the dog recognize novelty? How do some dogs behave better than others when it comes to certain kinds of stimuli? And how does that relate to our very being as human beings, which is the key of course in neurobiology because it's at the center of human concern. Our brain and body are us.

ALAN ALDA: (Narration) Lately, Gerry Edelman has been turning his thoughts to a mystery so profoundly personal that it has always seemed beyond the reach of science: the unique world within our own heads we call consciousness.

GERRY EDELMAN: We all know what consciousness is, without having to ask a philosopher. It's what you lose when you fall into a deep dreamless sleep, and what you regain when you wake up. So we have a sense of it, even if we can't put it into words. And so the problem is this: How do you make it a scientific subject? How do you actually investigate such a remarkable thing since it belongs to each individual to some extent privately?

ALAN ALDA: So is this an attempt to make it a scientific investigation? Consciousness itself?

GERRY EDELMAN: Exactly. It is indeed. It's to find what they call in the fancy language, the neural correlates of consciousness. What happens inside your brain when you actually become conscious of something. Well, Alan, let me introduce you to Lacey, who's the lady who really knows how to work this thing.

She's going to take you inside and expose you to this remarkable miracle of modern science.

ALAN ALDA: (Narration) I thought allowing scientists to eavesdrop on my dreams was pretty brave

ALAN ALDA: Hello?

ALAN ALDA (Narration): But allowing a machine to peer into my consciousness? The plan here, as I understand it, is to see what happens in my brain as my consciousness switches from an awareness of one thing to an awareness of another. What looks like a giant hair dryer is actually a machine for picking up the tiny magnetic signals my brain gives off as it busies itself interpreting the world. In this experiment, my world is limited to the screen in front of me. To you it looks like a flickering plaid of blue stripes and red stripes. But the glasses I'm wearing limit my right eye to seeing only the blue stripes, and the left eye to seeing only the red stripes. My brain can't handle these two different signals at the same time, so it chooses to be aware of -- to be conscious of -- only one at a time. Every couple of seconds or so it spontaneously switches -- now I'm aware only of horizontal blue stripes, now only vertical red ones. As I record which color I'm seeing, the machine is recording which parts of my brain are responding. It turns out that neurons fire in response to both red and blue even when I'm conscious of only one. But there are many regions of my brain where the response to a color is much stronger when I am conscious of it. It's as if the blueness, say, is always there, but springs vividly into my consciousness only when a vast network of neurons ignites together.

GERRY EDELMAN: So think of a kind of flame playing back and forth, back and forth. The flame is the consciousness if you will, but there's no one place where the consciousness is.

ALAN ALDA: (Narration) The flame flicks between regions of the brain involved in memory as well as those processing new information from the senses. Edelman and his colleague Giulio Tononi have taken snapshots of this metaphorical flame in seven different subjects like me. At first glance, the flames look similar.

GIULIO TONONI: But in detail, if you look at it, all people are different.

ALAN ALDA: The same thing is happening but it is happening seven different ways because you have seven different people.

GIULIO TONONI: Seven different faces, seven different brain activity patterns when you are conscious.

GERRY EDELMAN: Seven different signatures when you sign something. And therefore one of the remarkable conclusions we've come to is I believe non-trivial to human beings. Individuality matters.

ALAN ALDA: (Narration) There's an even more remarkable conclusion for non-humans. Having an idea of what consciousness is means you could in principle install one in an artificial brain like Darwin's.

GERRY EDELMAN: When you synthesize it, it is not going to be like

ALAN ALDA:, certainly not. It doesn't have your body, it doesn't have the same kind of structure. So it will be a consciousness. Now the question becomes, how do you check it?

ALAN ALDA: Yeah, I was going to say, if you can get Darwin to be conscious, how do you get a report from Darwin?

GERRY EDELMAN: You would have to have something like language. Higher order consciousness. Because otherwise you could only surmise that it was conscious.

ALAN ALDA: (Narration) Knowing what consciousness looks like means you could also search for it in non-human animals. Edelman has little doubt that an animal such as a dog would turn out to possess at least the glimmerings of a consciousness flame.

GERRY EDELMAN: The difference between a dog and you however, or Giulio let's say, is that if you kick a dog the next time he may bite you or run away, but he doesn't sit around plotting to remove your professorship!

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THE POWER OF HALF

ALAN ALDA: (Narration) We're ending our show on brain plasticity with a truly astonishing example. I'm with Jordan Grafman, looking at the brain scans of a remarkable young woman.

JORDAN GRAFMAN: This is the right side of her brain; this is the left side of her brain. And what happened was, in utero, she had a stroke. And the stroke, not entirely, damaged a large proportion of her left hemisphere.

ALAN ALDA: So that never developed?

JORDAN GRAFMAN: Never developed.

ALAN ALDA: What is the left hemisphere usually there for?

JORDAN GRAFMAN: Verbal processing. Language processing. Not all aspects of language by the way, but enough that we consider it the hemisphere that really dominates our language abilities. It also plays a fairly large role in recognizing objects. Our ability to look at objects to know what they are and even how to use them.

ALAN ALDA: So if those functions of the brain were only to be found in that area, then you'd expect that a person without that part of the brain would have difficulty saying words or recognizing objects. But this is not the case with Michelle?

JORDAN GRAFMAN: This is not the case with Michelle.

ALAN ALDA: (Narration) Missing almost the entire left side of her brain, Michelle Mack has an obvious problem controlling the right side of her body. But at the Catholic Church where her mother works, it's equally obvious that Michelle has few problems either with language or recognizing objects. She regularly helps out with the church records.

MICHELLE MACK: I take them home and I update them on my computer at home and I bring them back to my mother and I file them.

ALAN ALDA: (Narration) Recently Michelle's mother Carol contacted Jordan Grafman at the nearby National Institutes of Health outside Washington DC.

CAROL MACK: I wonder what testing Dr. Grafman will be doing.

ALAN ALDA: (Narration) Every month or so now, mother and daughter drive to the NIH to join Grafman and his team in a study of how Michelle's right brain copes with a workload most brains share with the left. Today, Carol told the film crew of a skill even Grafman doesn't know about.

ALAN ALDA: If I say a date, you can come up with what day of the week it is?

MICHELLE MACK: Yeah, I think so, yes.

ALAN ALDA: Well, let me not go too far out. Let's say this year, the year 2000, October 19th.

MICHELLE MACK: OK. October 19th is going to be on a Thursday.

ALAN ALDA: OK, I don't have a calendar so I can't check that. So far you're doing great. OK. So let me go a year later. The year 2001, August 12th.

MICHELLE MACK: OK Sunday.

CAROL MACK: They're all checking! (Off camera) They're both right.

ALAN ALDA: They're both right?

CAROL MACK: They're both right.

ALAN ALDA: Maybe we should stop at 100% correct, right? That's amazing.

MICHELLE MACK: That's great. I hope this is on tape.

ALAN ALDA: Did you know she had this ability?

JORDAN GRAFMAN: Not until right now. And that's why it's fun to work with Michelle because she's always surprising us.

ALAN ALDA: (Narration) Jordan's work with Michelle is only beginning. But already it's apparent not only that her right brain has taken on tasks usually done by the left, but that it's had to make some changes of its own. For instance, Michelle has problems with tests of her visual-spatial skills, even though her right brain -- where these are normally tackled -- is intact.

ALAN ALDA: It's almost a question of geography. Like there's a whole bunch of word people who have no place to live on the left side, and they're crowding on to the right piece of geography and there's only a certain amount of land there.

JORDAN GRAFMAN: They're not asking permission.

ALAN ALDA: That's right. They're coming in, they're barging in and the folks who are living there who handle spatial stuff are getting crowded out. Not as many of them can do the spatial stuff. That's what it sounds like is happening.

JORDAN GRAFMAN: Couldn't have said it better!

ALAN ALDA: But that's fascinating isn't it. I mean there's this old saying that you hear all the time, you know, we only use 10% of our brain. It sounds to me we're all using every bit we've got.

JORDAN GRAFMAN: Every bit we've got, and we'd try to stake out more if we could.

ALAN ALDA: Right. And it's almost as if there are parts of our brain competing.

JORDAN GRAFMAN: Exactly.

ALAN ALDA: for a place to work.

JORDAN GRAFMAN: Exactly. As you learn new things, there's always somewhat of a cost. There's a finite amount of space and a finite amount of tissue, and you can enrich that tissue but you're also going to compete with adjacent territory as you learn new skills and have new abilities. And you use the whole brain, and the whole brain is a competitive organ. Each piece of the brain is competing with its neighbors to get more territory, to have more action. And it's happening now in you and it's happening in Michelle as she takes the tests and develops throughout her life.

ALAN ALDA: (Narration) As we said at the beginning of our show, we're all having to change our minds about our brains.

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