>> Steve Langjahr: I'm told it's March 16th, 2015, and this is lecture 11. Our last episode, if you want to call it that. We looked at a simple reflex which brings about movement. But surprisingly doesn't involve or require the brain. A reflex requires a receptor, a sensory nerve, intact spinal cord, motor nerve and some sort of muscle or gland. But today we're going into the very astounding area of brain science literally and trying to unravel as best we can how the brain processes sensory information. It's probably hard to accept this, but in your brain right now there is no pain. There's no light. There's no sound. There's no hot. There's no cold. It's just action potentials. And everything we feel and everything we care about, our entire existence or even our awareness of our existence, is action potentials. So it's quite incredible thought to ask how does the brain make sense of these action potentials, which are fundamentally just electric signals? So how does the brain decode the sensory information that's coming to it only as action potentials? Essentially, diagrammatically, it's easy to illustrate receptors in our skin or throughout our body, respond to environmental stimuli. These are producing receptor potentials which then create action potentials that are propagated toward the spinal cord. In the spinal cord those action potentials are T word, transmitted, and therefore, propagated up the cord, eventually to areas of your brain where you decode that information. That is, you make sense of whatever it is. So our goal tonight is at least to shed some light on the aspects of sensory interpretation. So first on the agenda, how does the brain decide or determine the modality of the stimulus? How does it know whether this is hot or whether this is cold? How does it know whether it's sound or whether it's light? Remember, action potentials are fundamentally the same. So interpretation of sensory type is really, really in the hands of the receptor because we said receptors, S word, were very specific. So, essentially the brain trusts the integrity of these receptors. Right now, if we could reach inside your brain and stimulate the auditory nerve, remember that box yesterday, the stimulator? What if we stimulated the auditory nerve just with signals from that box? Those signals would go to the brain, and the brain wouldn't think of them as painful or jolting in any way. We'd be interpreting as what? Sound. So essentially the modality is dictated by the specificity of receptors. And so we have dedicated avenues of information called the specific labeled sensory pathways which are exclusively devoted to a certain kind of stimulus. Maybe this diagram will help. Here's the spinal cord. Out here in the fingers or toes or whatever we have some receptors shown here as blue circles. And let's say these receptors are sensitive to heat. Notice they're a little overlapped, but notice that they each have their own dedicated axon, and these axons travel together toward the spinal cord. And they synapse there with fewer numbers of ascending fibers. But the point of this diagram is to emphasize that this pathway is dedicated to and only carries information about, in this case, heat, right. Is there a mingling of other sensations in there? No. So we call this a sensory unit, which is composed of identical, specific receptors. And this information is carried faithfully without getting scrambled or contaminated or mixed up with anything else. And it's carried vertically through ascending tracks. And so when signals reach the brain, along this pathway, they'll be interpreted always as heat. Because the brain, again, respects and trusts the integrity of the receptors. So these pathways up the spinal cord are just that, sensory pathways which have consolidated, that means brought together, unmixed sensory units. So there's no mixing up of sensations. That is, these pathways are dedicated to and carry information about just discreet kinds of modality or sensory information. Here's an interesting thought though. Remember these receptors were sensitive to what? Heat. So I'm showing a heat source here just to make it graphic. And this heat source is applied at this location. Notice obviously that it would affect this receptor more than that one simply because this one is closer to the heat source, right. And so which of these three receptors would develop up the great receptor potential, obviously that one. And so this series of hatch marks there represents the action potential frequency which is derived from these receptor potentials. This goes back to Monday's topic. But still, this information gets consolidated. That means squeezed down on to fewer axons, and is carried faithfully up to the brain. And the brain interprets this as being heat. Here's an interesting thought. What if this axon here were to be cut selectively and lose its connection then with this receptor? And let's say even more unlikely, that axon were to grow into another receptor in the area, but a totally different receptor. So I've shown this cut axon finding its way into a Pacinian corpuscle instead of back to this receptor where it was normally or previously connected. So what? Well now this axon which was and still is part of this sensory unit would respond not to heat but respond to pressure. So if we touch this area, that information wouldn't be interpreted as touch, but, as always, the brain would interpret it as heat. So there would be some confusion there. And if this doesn't make any immediate sense, let's just take a striking if not Frankensteinian possibility. What if we took your optic nerve and clipped it and then could splice it into your auditory nerve? What then? The receptor, that is the photo receptors in your eye which still, as always, respond to light. But that information would be interpreted not as light but as sound. Again, the brain is accustomed to assuming that any information over the auditory nerve is what? Sound. And it does its best to organize and interpret that sound. So these ideas might be abstract or even hard to understand at first, but let's just give you an example before we leave this category. We said that there are dedicated, exclusive, sensory pathways that carry information only about this or only about that. And we'll give you a couple of

examples. From anatomy you might remember that there's a tract, an ascending tract, called the anterior spinothalamic pathway. And it's dedicated to, that means it carries signals only about what? Touch and pressure. So it's exclusively concerned with carrying these kinds of sensations. Interestingly, this particular tract is made up of neurons which happen to be very, very well myelinated. In fact, neurons are classified by their degree of myelin. A fibers, B fibers, C fibers, it's just an arbitrary reference. But the important part is, what does myelin have to do with the speed of propagation? Does myelin improve or slow down the speed of propagation? So these are A fibers, which are very, very well M word. And therefore, they conduct signals. They propagate action potentials pretty quick. In fact, you don't need to memorize this, but just to put it on paper it's, well, 70 to 120 meters per second. Okay so what? In the spinal cord there are a number of other tracts. Let's pick on this one, the lateral spinothalamic pathway. And this one is dedicated to something very different. It carries information about what? Temperature and some pain sensations, okay. Where are we going with this? This tract, the fibers are much less myelinated. They're thin and poorly myelinated. In fact, they're designated C fibers. What does that have to do with it? If they have less myelin, are they going to propagate faster or slower? Slower. Quite a bit slower. Pokey really, 1 to maybe 20 meters a second. Alright so this is interesting, but so what. What we're trying to use this for is to convince you of this distinct, dedicated, quite isolated arrangement of sensory pathways. Basically that some pathways carry some information, others only others. And this is something that you can I think validate from experience you've had in the kitchen. So you've got some pots on the stove, right. Water is boiling, whatever. And you reach for the handle of that pot. And you move it off the stove. You're not wearing gloves or a potholder. From that experience, that is, this has happened to me I know. Do you register, are you aware of, contact with that handle or the temperature of the handle, or are they simultaneous? Which comes first? You might say, well they happen at the same time. No they don't. Because if they happened at the same time you wouldn't even begin to take it off the stove, right. Hasn't this happened to you? Grab it, whoa, that's hot. So you recognized what first? You recognized the touch. And then a little bit later came the temperature. Illustrating that these very different types of sensations are carried on different tracts. And like it or not, the temperature gets there a little bit later, so creates a little embarrassment there in the kitchen. So this is all about sensory type or modality. Next question. How does the brain decipher or calibrate or estimate how intense something is, how strong a particular sensation is? How does it estimate the magnitude of whatever it is? Is this just warm, or is it hot? That's what we're talking about. How does the brain determine warm from hot? Is it because the action potentials are bigger or smaller? Nope, because action potentials are what? All or none. So it can't be the amplitude of the action potentials. And so what's the only other option for communicating intensity? It's not amplitude, it's frequency. So tapping this out. This is a certain what? Frequency. And this is a greater frequency. What does the brain think about that? No big deal. That gets the attention. So estimation of the magnitude is a function of action potential frequency. And it's also a function of the number of active sensory units that have actually been stimulated. The analogy I use here, which may help, is this question. What determines the level of applause in an auditorium? What determines how loud that applause is? If we accept the notion that everybody in the audience makes the same noise when they bring their two hands together, the overall volume of the applause is a function of how many people are what? And how frequently they're clapping. So it's not just a matter of frequency, it's a matter of the number of sensory units that are actually responding. So simply put, if you dip your hand in warm water, we get a certain number of sensory units responding at a certain F word. And then if we move it over to real hot water, are more sensory units going to be activated? And are they going to be producing a higher frequency of action potentials? Yep. And the brain takes that to be whoa, that's hot. Next topic number three. It's nice to know how intense something is, and of course it's important to know what it actually represents. But localization is pretty important. How does the brain decipher where on the body this is? And that's pretty important because if we don't know where it's coming from, we have no way to investigate or otherwise respond appropriately. So this information that's going to work its way up to the cerebral cortex, first of all, stops at the thalamus. The thalamus is part of the forebrain, but it's not the last stop. In fact, it's probably the first stop if you want to call it that. The thalamus, as you know, is deep within the cerebrum. It's an area of gray matter which receives virtually all sensory information. And its job is to decipher approximately where in the body this came from. And then route it to more precise areas of the cerebral cortex. So the analogy that's usually used here is this, you know, you have a big office building, phone, phone messages come into sort of a switchboard. And then those calls are routed to this office or that office, you know, you've had that. Can you connect me with. So the thalamus is a crude determinant of where in the body this stuff came from. And it also determines the basic nature of the stimulus. But it's not the final, the final evaluator here. It basically sets up an early, primitive, crude expression of localization. And from here, the information, the sensory action potentials are directed to specific sites in the cerebrum. If you recall a little bit of anatomy, you might remember this sulcus here, which is called the central sulcus. And just behind it right here in orange actually, is what's called the primary sensory area. So virtually all information, especially from the skin, touch, temperature, pain, ends up being analyzed right here. And that area is called the primary sensory cortex, which is devoted to precise localization of this information. Here's a slice, so if we go back, whoop, go back to this view and just cut right down here frontally, we would reveal this. Of course it's not going to have words on it. So this is the medial to lateral profile of the primary sensory cortex. And, of course, these words aren't there, but we know from experimentation that this cortex is actually laid out, that is parts of the body are represented here, just as shown. So, as incredible as it sounds, if we were to have your cranium opened, and your brain right there, and this can be done, and we were to stimulate that area right there with a probe, an electric probe, what would the conscious patient report? They wouldn't say oh you're poking my brain there. No. They would feel something, where? On their thumb. And incidentally not the same side but the opposite side. So this is essentially what's now described as a map, which is literally draped over or laid across this so-called primary sensory cortex. Sensory areas are mapped out along this sulcus, which is just posterior to the central sulcus of the cerebral cortex. What's interesting about this map is that bodily parts are not equally represented and certainly no reflection of their actual physical size. For instance, is your back a pretty big area? But yet if you look on there, the back doesn't get much representation. And by the same token, your lips aren't that big, but yet they get a lot of representation. In fact, the face is overrepresented you could say. And that seems unfair or at least peculiar, but yet it connects with what we know. Where do we have the greatest ability to precisely locate things? When somebody says here, check this out. You don't say, put it on my back there so I can feel it better. No, you say put it in my hands, right. As another example, I'm sure you've gotten wood splinters in your fingers. And sometimes you can't even see those splinters because they might be a light colored wood. But yet even if you can't see them with your eyes. You know exactly where it is. And I do this all the time. I say to my wife, I know I've got a splinter in there. I can't see it. Can you get it out? She says, well if you can't see it I can't see it. So I just navigate her. She's there with the needle and I say okay, a little more medial, a little more lateral. So she goes in and gets it. So I'm directing her just with words based upon her probing. And our fingers highly represented on this somatosensory cortex. Absolutely. As they should be because where do you interact with your environment? Right there. Right there in your hands. So this might seem, well too preposterous to believe. But it's very important, not only in terms of academics, but in terms of surgery. Do patients sometimes need brain surgery? Of course. There might be a tumor in there that has to be removed. And that's a challenge. Yeah we could remove the tumor, but do you want to remove healthy tissue at the same time? You don't want to say, well we'll just go in there and scoop something out and then see what happens later. So actually, most brain surgeries, especially for tumors, the patient is awake. The skull has been opened, the brain is right there. You say whoa, how could somebody stand that? Well there are no pain receptors in the brain. So you can probe around there all day and not get any pain. And so what you're about to see is a video which shows this kind of brain mapping for a patient who is undergoing surgery for a tumor. And his profession is actually a musician. And so they want him to sing during the procedure because that way they know as long as he's singing, they're not disturbing anything that would jeopardize him later. So let's show this. It's only about five minutes, but I think it'll illustrate this point better than I can do by words alone. Alright. Okay. It's catching up.

>> It's early morning at UCLA Medical Center, and Dominic Bakewell is preparing for the surgery that he hopes will save his life.

>> The first procedure was four months ago, and I was more nervous during MRIs than I am today. I'm ready.

>> [Inaudible] MRI revealed cancerous tumors surrounded by several breakaway areas, regions that govern his motor movements, his speech, his ability to make music and the fiber tracks which convey that information.

>> [Inaudible] what looks like a cut up of fibers. Luckily, [inaudible] the fibers running through the tumor, it was just kind of sitting around it. So it's [inaudible].

>> Dominic will be kept awake through much of this surgery to minimize the possibility of losing crucial brain functions. But in an operation this perilous, there are no guarantees.

>> There is a [inaudible] may not be able to talk. With the awake mapping that's obviously what we're trying to avoid, the complication of him not being able to talk or having any speech problems after surgery.

>> Dominic's head is now immobilized in a halo-like [inaudible] to prevent even slight movements during the operation. Dr. Liau cuts his skull open directly above the tumor. Dominic is unconscious for this part of the surgery.

>> The tumor is right in this area right there. You can see this [inaudible] is much more swollen than the other one right next to it. So these are relatively normal, whereas this one really doesn't.

>> But the tumor is tightly surrounded by vital brain matter, regions that control Dominic's movements, his speech and his music. To precisely map those boundaries, Dr. Liau probes his brain's motor areas and electrified [inaudible]. Though Dominic is asleep, his body physically reacts to stimulation of regions controlling his muscle movements.

>> So this is all just [inaudible]. We're not doing any brain mapping yet.

>> Once she has thoroughly mapped his motor functions, Dr. Liau is ready for the surgery's crucial moment.

>> I think we'll wake up and listen to him sing.

>> Testing Dominic's ability to talk and to sing while she removes his tumor, there's just one thing left to do. Wake him up.

>> Dominic, this is Dr. Liau.

[Inaudible Speaking]

I'm putting some local anesthesia in your muscles right now, okay.

>> Though Dominic's skin feels sore, the brain itself has no nerves to stimulate pain. Once he's fully alert, Dr. Susie [Inaudible] asks him to identify pictures and words on flashcards.

[Inaudible Speaking]

As Dominic answers the questions, Dr. Linda Liau uses an electrified wand to touch areas around his tumor where he generates speech. If she hits a live area that transmits language, Dominic's ability to reply will momentarily short circuit. A clear signal for Dr. Liau to leave that region alone.

[Inaudible Speaking]

Dr. Liau maps those areas with lettered markers.

>> [Inaudible] we'll just avoid that. [Inaudible]. Let's try again at 14.

>> Once she's determined what's safe to remove around the tumor, Dr. Liau prepares to cut it out while Dominic is awake.

[Inaudible Speaking]

Dr. Liau depends on Dominic's answers to gauge how aggressively she can remove areas near his tumor without damaging vital functions. If she makes a mistake, Dominic will be a witness to his own tragedy. As she cuts out the cancer, the soft brain matter around it should fill in the whole, putting more healthy tissue at risk. So Dr. Liau must keep on probing, as Dr. [Inaudible] monitors Dominic's responses.

[Inaudible Speaking]

Dominic's vital signs remain stable, but now as Dr. Liau needs him most, he teeters on the edge of sleep. Suddenly Dominic's brain rebels. Without the sedative of anesthesia, awake brain surgeries are susceptible to sudden seizures, especially while the brain is being stimulated. This one's too small for Dominic to notice.

[Inaudible Speaking]

But continued stimulation of the brain can turn small seizures into bigger ones. There's nothing to do but anxiously wait out the episode.

>> Is it over? Okay, we only have a window of time here.

>> Delays during surgery increase his risk. So once the seizure stops, Dr. Liau moves quickly to a part of the tumor near where Dominic's brain creates music. It's time for him to sing.

[Inaudible]

As long as Dominic sings, Dr. Liau knows she's on safe ground.

>> That's really good.

>> His singing helps Dr. Liau finish removing the tumor quickly and with a minimal loss of blood. Now Dominic is ready for a well-earned nap.

[Inaudible Speaking]

Non-magnetic titanium brackets and screws help put Dominic's skull back together. The full centimeter tumor is out and ready to be taken for biopsy. For now, the operation appears to be a success.

>> Steve Langjahr: And it was, just to cut to the chase. An incredible combination of skill and technology. Here's another video that's equally intriguing I think. Perhaps you've heard that occasionally when someone suffers a lot of trauma, let's say in an auto crash. They may have to have a limb amputated before they regain consciousness or even before they're aware of the severity of their injuries. So incredible as it sounds, they sometimes recover from anesthesia and complain about pain in their hand, only to discover that they have no hand. That it's been removed. So how can that possibly be? I mean the hand's not there anymore. The nature of that sensation, the description of that sensation is something called phantom limb sensation. And as incredible as it sounds, and you might dismiss it as just some sort of psychological misinformation, is the stump still there? Does it contain sensory nerves that used to originate in the now missing hand? And can those neurons at that level be stimulated? And will those signals go to the same area of the brain that registers and interprets information from the hand? So would the patient actually feel the same, that is feel this as a hand even though by all accounts that hand is not there. And yes, the nature of that is called phantom limb. And the explanation of that has been worked out to some degree. And this is an interesting segment on that topic of phantom limb sensation. Much of this being worked out, incidentally, by California researchers. Oops, did I press the wrong one? Apparently. Sorry. Back to menu. Uh-huh. Sorry. View, fit screen, enter full. I pressed this one I thought. Alright, we'll do it the hard way. This actually is the easy way.

>> Come for amputees to feel the vivid presence of a missing limb long after it has gone. One of Dr. Ramachandran's first patients was Derek Steen.

>> Thirteen years ago I was involved in a motorcycle accident, and I pulled the nerves out of my spinal cord up in my neck. They told my parents directly that I would never use my arm again. About seven years ago I was reading through the classifieds, and I saw an ad in there, amputees wanted. I thought it was a joke.

>> It's just basically connecting the club to the ball.

>> So I called the number. And it was Dr. Ramachandran.

>> Today, Derek is teaching Ramachandran how to play golf.

>> Beautiful.

>> But several years ago, Derek made a crucial contribution to Ramachandran's pioneering work in brain science.

>> Yeah, that was amazing.

>> After my surgery I sat up in the bed and still felt the arm there, still felt everything there, and I'm looking down and I'm seeing nothing. It was pretty bizarre. The more I thought about it, the more it hurt. The more it hurt, the more I thought about it. So it was like, it was never ending. I mean I'd break out in a cold sweat and turn pale just standing here talking to you because the pain would hit so bad.

>> If there is one thing about our existence that we take for granted, it's the fact that we have a body. Each of has a body and you give it a name, it has a bank account, and so on and so forth. But it turns out even your body is something that you construct in your mind. And this is what we call your body image. Now, of course, in my case, it's substantiated by the fact that there really is a body with bone and tissue. But the sense I have, the internal sense I have, of the presence of a body and arms and all of that, is, of course, constructed in my brain. And it's in my mind. And the most striking evidence for this comes from these patients who have had an amputation and continue to feel the presence of the missing hand.

>> When I first started shaving after my surgery, I would feel my absent hand start to hurt and tingle whenever I shaved this left side of my face.

>> Meeting Derek was important for Ramachandran because the explanation he came up with would rock the world of neuroscience. The first thing Ramachandran did was to invite Derek to his lab for a simple test.

>> Derek, I'm going to touch different parts of your body. I just want you to tell me what you feel and where you experience the sensation, okay?

>> Okay.

>> Close your eyes.

>> I can feel that on my forehead.

>> Anything anywhere else?

>> No. On my nose.

>> Okay.

>> My chest.

>> On your chest? Okay.

>> I can feel that on my cheek, and I can feel rubbing on the phantom left hand.

>> On the phantom left hand, in addition to your cheek? I'm going to run the Q-tip across your jaw and see what happens.

>> I can feel the Q-tip on my cheek, and I can feel a stroking sensation across the phantom hand.

>> You actually feel it stroking across your phantom hand? So here is a medical mystery of sorts. Why does this happen? Why would a person, when you touch his face, claim that it's also touching his missing phantom fingers?

>> This was just the kind of mystery that Ramachandran was drawn to, although it would take some time to solve. One

day, while Derek was making one-armed repairs on his favorite Chevy, Ramachandran turned up with his solution. It was a groundbreaking theory.

>> The reason we think it happens is that in the brain there is a complete map of the surface of the body. The entire left side of my body, the skin surface, is mapped on to the right side of my brain along a vertical strip of cortex which we call the somatosensory cortex. Similarly, the right side of my body is represented on the left side of my brain. So every point on your body surface has a corresponding point on this body map. Now, it turns out that the representation of the face on this map is right next to the representation of the hand. Now that's a bit surprising, as you'd expect the map to be continuous and faithfully represent the left side of my body. But it doesn't. Now imagine what would happen if the left arm were amputated. The part of the brain corresponding to the hand no longer gets any input, and it's hungry for new sensory input, so to speak. The sensory signals from the face normally activate only the face area that's right next to the hand area. But they now invade the vacated territory corresponding to the missing hand and start activating the hand region of the brain. And so whatever is reading those signals higher up misinterprets those signals. It says those signals are coming from the missing hand. So you experience the sensations as coming from the missing fingers even though I'm touching your face. This is showing there's been a massive reorganization of the sensory pathways in your brain after the amputation. And it's as though there's been a cross-wiring in your brain.

>> Exactly. Exactly.

>> Steve Langjahr: That's pretty spooky. But it's not fiction, it's the real deal. Another example of that which is pretty easy to predict at this point, it's not uncommon for people who suffer frostbite of the face, extreme cold, that the skin of their nose will be destroyed because of the bitter cold, especially obviously for mountain climbers. So essentially that skin falls off, and you have just a big hole there, which is cosmetically a little disturbing to say the least. So how do surgeons reconstruct the skin around the nose? And interesting way to do it is to cut an incision into the forehead, because there's plenty of extra skin up there, and then take that triangular piece and just rotate it around and then rebuild a nose from this skin that is still connected to nerves and used to be, of course, a part of the forehead. Let's be clear, we're not taking that skin off and putting it down here. We're just peeling down and turning it around. The nerve supply to that now new nose still goes where? And so now, when someone touches this new nose, the patient says, or otherwise claims, to feel what? Somebody touching their forehead. So these are hard to accept maybe, but they demonstrate the mapping of the brain both in a sensory and in a motor context. Thanks. So moving on. Summarizing some of these topics, I think we already knew that the map on the left is getting information from the right side of the body. And the cortex on the right, of course, receives information from the left side. You know about crossing over of these tracks in the brain. This is a kind of cute, if not silly, illustration. And you wonder what's going on here. It's an attempt to show what areas of the cortex have the most representation. And notice the hand gets a lot of attention, the lips and the face, but the rest of the body gets short changed, simply because these are the areas of the body that interact in a tactile way with the environment around us. So not only is this map not continuous, but it's not fair in the sense that some areas have greater representation than others. Finally, as a remark on this page, the determination of the exact location of something is not just a matter of what area of the somatosensory cortex is receiving information. But it's also a matter of what areas are not receiving information. In other words, it's much easier for the brain to pinpoint a particular source of information if it has relatively inactive areas adjacent to it. Now I know that's an abstract sentence. So imagine this hunt for that splinter that we talked about a moment ago and how I was able to direct my wife to that splinter even though I couldn't see it. But let's say now I have my hand under water or attached to a vibrator that's doing that. Would that make my ability to guide her in easier or harder? Clearly harder because there would be so much other competing information. So it's not just what area is active but what areas are inactive which help us really zero in on the location of a particular stimulus. So it's fascinating, but functionally just a processing task of the somatosensory cortex. It's one thing to know what the stimulus is. It's another thing to know how intense it is. And it's certainly important to know where it is exactly. But oftentimes there's more to appreciate. There's more to deduce than just those three things. What were the three things? What is it? How intense it is, and where is it. Those are fundamental. But beyond that, there's a little more processing that always takes place, and that is, simply put, what does it mean? Is this something I should be worried about, or is it no big deal? Another words we're going to analyze its implication. And so we'll call this stimulus association based upon previous experience. Is this something we should fear or otherwise enjoy? And this analysis if you want, is really determined or shaped by two parts of the brain which cooperate or communicate you could say. The first is called the parietal association area, which is basically just behind the primary sensory cortex. To go back to our map, this orange strip is the primary sensory area. But all of this green is the so-called parietal association cortex. And

this provides some analysis regarding previous experience. Have I felt this before? And do I remember or have anything that really I should remember or utilize in this sense? It helps you do more than just say yeah, that's hot. It's in my finger. But rather, what might it be the result of? Evaluating subtle things like what shape, texture and ultimately determining the implication. I should have brought this in, but a couple Christmases ago I got my grandson this toy in the mall. It wasn't really, it's not a toy in the sense of a robot or anything. It's a game actually. And it's really cool. It's an enclosure made of nylon, and inside are all sorts of objects of various size and textures. And so the game is you have the deck of cards, and it shows okay, octopus. And so what do you do? You stick your hand in there and you hunt around and try to find what? The octopus. Using nothing but your hands. And yeah, you can do that, of course. What enables you to do that is this parietal association area. And never mind that game. You can reach into your pocket, and if there are keys in there, can you fumble around and probably pull out your car key amongst all the others that are on that key ring. Do you think you can do that? Sure you can. Why? Because of previous experience. You know what it looks like. You know what it feels like. And using just the information coming to and through your fingers, you can evaluate shapes, textures and determine the implication of it. Is this my house key? Is this my car key? Is this a quarter? Is this a penny or something like that? So quite remarkable. But this is essentially objective, objective. Meaning it's a matter of comparing this information to previous experience and making an assessment. Actually giving it a name perhaps. And so impressive, but it's not all there is. Most often it doesn't stop there. Because now the frontal association area right here gets involved. And its concern is not objective but subjective. In other words, it provides information from previous experience which could be described as emotional, emotional connotation of that thing. Does it have any emotional elements to it? Certainly your car keys probably don't evoke a lot of emotion. But other things do naturally. What if we were to turn on the TV as we sometimes do, and we see a news story of flooding in the Midwest or something. And people are dying and suffering, and it's a tragedy. Now that's a visual image. Yeah floods, yeah, yeah. But is everyone going to react to that the same way, even though objectively it's the same image. It's the same image to everybody. But some would do what? Some would say, OMG, I got to write a check here and send it to the Red Cross. Some would just flip over to the Kardashians and forget it. So, what is it? The image is the same, but the emotional context is much different. I should have done this because it would have been the perfect opportunity. I could put up a picture here of Donald J. Trump, alright. And even though it's the same picture for everybody's retinas, would it evoke the same response? Hardly. Some would be waving the flag and can't wait to get to the polls. Some are just uneasy and, you know, alright. So this is, this is what the frontal association cortex does. It gives us that emotional element which really, it really differentiates us from robots. Because all though we don't have robots that can do this, ultimately we will. And the robot would say, Donald, Donald J. Trump. Businessman, whatever. You know, but that would be it. There would be what, no emotional or motivational element. What's motivational element? If Donald J. Trump becomes a candidate for the president, I'm going to be motivated to vote. Not for him, but that's another story. But I'm going to be motivated, you bet, anyway, I'm sorry if I offended anybody. I'm just giving you my personal opinion. And you're entitled to yours. Now, what was that? That wasn't Donald J. And I'm not going to put it up there again, because if you miss it, you miss it. What was it? That was George W. Bush for .5 seconds. So not only does this relate to our own experience, but isn't it incredible how quickly we can process this information and make a judgment and have a feeling about it. It really is just that. And I tried to get this to work, but there's always a technical glitch. I had recorded some sounds that I was going to play back. Because certainly we can react to the spoken word. Or for that matter, a singing voice. You know, we might be really moved to tears with Celine Dion or something. But it doesn't have to be words. The example that I was going to use, and I still have it, was actually dogs. Which of course, don't speak as far as we know. And I had three dog things. One was kind of a whimper. Once was a grrrr. And my plight, which you just have to imagine now, is that even though that's a nonverbal thing, is there a lot of information in there? Yeah. So if you approach a house and you hear mi, mi, mi, mi, some sort of Chihuahua, you know, that's going to be different than if you, you know, hear something threatening or otherwise worth your attention. So my point there was simply that it doesn't have to be words, it doesn't have to be verbal. It can be very subtle cues. Again, all based on previous experience. Because if you've never heard a Chihuahua before, you might say well, I don't know what that is. But probably not a dog. Alright, moving on.

>> I have a question.

>> Steve Langjahr: Good.

>> Well, talking about [inaudible] and seeing the picture of Bush, [inaudible] like that, it like makes my skin crawl. It has nothing to do with skin, so why do you feel that?

>> Steve Langjahr: Well that's an autonomic response. And I'm glad you mentioned that. An autonomic response is what most people call a gut response. And some people use the expression, that makes me nauseated. Whatever it is. And yeah, you do have that sematic response because you are so, well I don't want to say irritated because sometimes it can be a very positive thing. You're so moved by it that you get goosebumps. You know, some people might get goosebumps with, you know, Celine Dion. Some not. Some might get goosebumps with, you know, the Kardashians. I don't know. But yeah, it is a real thing. And yes it has nothing to do with your skin. But it is an autonomic, sympathetic, parasympathetic activity of the smooth muscle, the blood supply and so forth. And certainly, I'm glad you brought it up. Do we all know what a blush is? Ooh, blushing. Well that's sometimes the result of embarrassment or whatever. But the point is it's an autonomic reflex after you have discovered oh, a faux pas there. It happens to me a lot when I call, that's the worst offense for me is calling somebody the wrong name. And so, you know, I probably do blush. But, you know, stuff like that happens. And it is just an autonomic reflex. But it isn't just a reflex. It's triggered by actual feelings, whether or joy or disgust that come from, in this case, the frontal association area. Moving on to five. An interesting topic, because it's one thing to know that someone's poking your left hand. But what about some sensation that's not even being applied to your skin? Right now I'm sending out some words out there, right. And that's not arriving or at least impacting your skin in any way. But it is entering your ears and your processing. It is sound, and beyond that, words that mean something hopefully. So, how do we locate things that are traveling toward us, to the left of us, to the right of us. You see if this room were totally dark, totally dark, your eyes would be useless. But yet amazingly, if I were to pace back and forth and deliver this lecture, and we could photograph you in total darkness, and that can be done, the interesting thing is everybody would be turning their head following me what. Even though they couldn't see me. And of course, well that's stupid. Why am I looking? I can't see him. But yet you do that in order to locate something. Because you don't have one organ for hearing, you have two, don't you? And ever stop to think why they're on the opposite sides of your head? I never did until I took this course. But some people say, well it's redundant. If you lose an ear you have a backup. Okay. But if that's the case, why don't we have an ear in the center of our back? It would be a little less obnoxious. Or just have an ear up here and just sort of have it, you know, laying out there. There must be a reason that they are absolutely equal distant on both sides of the head. That's because these identically tuned sense organs are processing information in a temporal way. Example. Happened years ago. I was sitting in our family car waiting for my son to get out of church. It was dark. It was summer. And the driver's side window was down, but the passenger side window was up. And I was just reclining in the driver's seat, sort of half awake, waiting for him to come out from this event. And I'm sort of half awake, but then I hear him say hey dad. So I opened my eyes, and I looked to my left expecting to see him. But no, he's over here. Now what happened there? Driver's side window what? Down. Passenger side window up. So this sound that's coming from there obviously can't get through here. Comes around here and enters this ear first, right. And then, that ear a split second later. How does the brain interpret that? Does it even care about signal arrival time? Absolutely. It judges arrival time in order to know where something is. Is it center? Is it left? Is it right. And that's what you're doing in this imaginary scenario where the world is dark. Why is your head following me? You're trying to find that sweet spot where the sound is hitting both ears at what? Exactly the same time. And then you know bam, that's where it is. And you might think well why bother? The room is dark. But is it always important to know where sound is coming from? If it's a bus, you'd better know that it's coming at you. And many other examples of course.

>> Is that also partly from your inferior colliculi?

>> Steve Langjahr: Well the inferior colliculus basically responds to approaching sound and gets your attention. But then you have to decide, you know, more about it. Is that sound approaching? Is it threatening? Is it important or not? So Peter's question is a good one. If that door were to open right now, everybody's head would turn because that's a reflex to the sound. And then, if that person coming in there is making, you know, a huge ruckus or something, then we might investigate more and otherwise turn, and our attention would be maintained. But basically where something is coming from, that is left of center, right of center or center, is a matter of mentally evaluating these bilateral inputs. So with that said, what if you only had one ear? What if you lost your hearing, would that make you deaf? No. You still have the other ear. But would your ability to locate things suffer as a result? It would. And in a similar way, why do we have two eyes? Looks better. No. Again, the left eye is seeing something slightly different than the right eye. And this information is then superimposed so that we have not a 2D but a 3D impression of what's going on. So, stimulus projection, that is knowing where something is, close, left, right, center, is a matter of evaluating this bilateral input that's coming from these two inputs. Bilateral comparison of stimulus arrival times. And the relative intensities. What does that mean? How do we know how close something is? Imagine this dark room again. And never mind it's me. We'll just have a sound

like a horn. How do you know if that horn is shifted left or right? It's this bilateral comparison. How do you know if it's coming close to you or retreating? That's volume, isn't it. And of course, these ideas are logical enough if you stop to think about them. And it's also the way that these ideas are conveyed in theaters. Is that train actually coming towards you on the screen? No. But how does it seem like it is? Well the volume is what? Ramped up. And so you get that sensation, that familiar scenario which you associate with approaching sounds or retreating sounds. And that's, of course, why speakers on both sides of the auditorium are great because then we can actually simulate the movement of something, an automobile, from left side of the screen to right side of the screen. So I know this is all sort of abstract and maybe a little intangible or you might not even thing terribly important. But it does show how the brain is masterfully processing just these signals and coming up with wondrous conclusions, even if it is just a disgusting feeling when you see a poster of somebody you don't like. That's it for tonight. And we'll catch you on Monday. Don't forget the weekly sample, examine. Please also turn in your exam. They're not yours to keep. But the cover sheet is. And I hope you do save that.