

The Science Studio With Rodolfo Llinás

ROGER BINGHAM: Welcome to the Science Studio. We're in the auditorium of the Salk Institute in La Jolla, California. My guest is Rodolfo Llinás who is Chairman and Professor in the Department of Physiology and Neuroscience at the New York University School of Medicine. Of course, we all come from somewhere, we all have roots, you haven't always been there. Where did you start?

RODOLFO LLINÁS: Yes well I was born in Bogota in Columbia. I studied high school and I did medicine there and then came to the states about 45 years ago.

BINGHAM: Now were your parents connected with the science at all?

LLINÁS: Yeah, my family has always been physicians so I have the fortune of having my grandfather and my father and uncles being part of the faculty of medicine. So it was indeed a medical family, if you like.

BINGHAM: Was there any particular influence, was there some scientist or was it literally your family that moved you in this direction?

LLINÁS: Well, obviously family moved me very much, but in particular, I had a very good relation with my grandfather who was professor of psychiatry-neurology, he is a neuropsychiatrist, a professor. I lived with him for a year as per his request.

BINGHAM: How old were you then?

LLINÁS: I was four. And I remember every millisecond of it. Really. It was so interesting. So there was this, he had this huge house and he lived by himself with people helping him. And so I was allowed to play in this huge house all day and he had his office where he received patients on the third floor. And this is memorable because it was so interesting, so I remember you would play around and you would look down on this waiting room and there'd be people sitting, not very exciting, its very long- I liked tentacle things so I had tentacle toys of all kinds and winding toys and so on. So one morning I look and there's this man sitting and he suddenly falls to the ground and begins to make very strange sounds and movements and my grandfather comes and they take him to the office. So at his office there is a bench and I'm waiting- hey grandpa, what happened to this person, why did he move like that? And make the sounds? Wasn't he ashamed? Didn't he, wasn't he bothered by doing these things?- Well he said, "he couldn't help it," I said, what do you mean he couldn't help it? He said well he didn't want to make these movements, the question is so if he didn't want to make the movements, why did he make them? And the answer was, well, you are not master of everything that happens. There is something

called the brain that you have inside your head and sometimes it does things that you don't want it to do and this is why he is coming here to see me because he is ill.

BINGHAM: So at 4 years old you were getting some basic neuroscience.

LLINÁS: And then the question is, what? Please explain! I can see it, it is so vivid and was so dramatic. In fact, in addition of this book in Spanish there is Garcia Marquez, who wrote a prologue for it and tells the story as he heard it. So it was in fact very important and it became clear that everything we do is the product of our brains, that without our brains, we'd be nothing. And then the question is, "Is music the brain?" Yes. Is language the brain? Yes. Is hating the brain? Yes. Is eating and hoping and knowledge? So is it the brain with just the body around to move or what? He said, more or less.

BINGHAM: Ok now in this book you just mentioned called *I of the Vortex*, you take the position that all these things you just talked about, the glorious things and the terrible things all coming from cognition, from the brain, from the mind- we'll get into what we mean by "mind" later- but you argue that all of that is really driven by movement, by the need to move, by the motion system.

LLINÁS: Absolutely.

BINGHAM: Could you elaborate?

LLINÁS: Yeah sure. If you look at biology in general, you find that suddenly in evolution, something very interesting happens which is macroscopic animals appeared. And what I mean by that is that a whole bunch of cells that had lived for almost 3 billion years as individuals suddenly came together to form an entity that is larger than any one of them, which is advantageous. You have more mass, you can interact with bigger things than you can as a single cell. A couple of things are very interesting. In fact, because of course when you do that, you buy death, which you didn't necessarily have before. Meaning as a single cell you live or die as per your state, but when you come together with others, when some of us die, you die as well. That is the ultimate commitment. It's very true. So, serious death appears after multicellularity appears. So it, as you know, it happened about 600 million years ago, which means that cells- this is important- cells took almost 4 times longer to be ready to make multicellular systems than the time required to make us. So one can almost say the cell element is more complicated or more difficult to evolve than us as a multicellular entity- important when we talk about feelings if we ever come to that, or qualia.

Ok so then you have a set of cells and this set of cells can solve the problem of existing in two very basic ways. One is to grow but maintain itself placed on a point in the ground, let's say you are a plant or you are a sessile organ- that would be something

that solves this problem by the universe coming to you, you cannot go to the universe. Those particular entities require no nervous system and have no nervous system- plants don't have a nervous system. The other solution is to move actively, to be able to displace yourself. Now in order to survive the dynamics of moving, you have to have some idea of where you are moving to. Now the advantages to moving are huge because you can run away from danger. This is non-trivial. If there's a fire and you're a tree, you die. If you are a mobile system, you run away from the problem, so there's an enormous advantage to motricity. The problem with motricity, with the ability to move, is that you have to have three very important properties. First, you have to have the ability to move in according to manner, to be able to displace yourself. Secondly, you're going to have to have some prediction of where you're moving into, so you need a sensory system that tells you, yes go there or don't go there, that you're moving to somebody's mouth so move away. And the third one, and the most profound, is called intentionality. To decide. If you have the ability to move and you have the ability to predict but you don't have the desire to move, you don't.

BINGHAM: Ok so we have this word motricity, which means ability to move, and you tell a story about some organisms that are sort of halfway between the sea squirt-

LLINÁS: Indeed. So the question of course came up, well ok Rodolfo, interesting but do you have a proof? And the answer was, yes in fact there's a beautiful proof, not my proof, it was taught me or I first heard it from Romer in a cerebellar meeting me had in 1968 when we were doing comparative physiology of the cerebellum and I was invited and this man who does evolution, he says well the only thing I can tell you is about this porifera, this coelanderate, that is sessile and when it reproduces, it reproduces by making a tadpole-like system that has an eye and has a vestibular system and so on and it moves around, when it finds a good place to become sessile, it becomes sessile, eats its brain, and basically becomes a plant again.

BINGHAM: So it gets to a point where its found an environment where it wants to be, it locks in to that environment, doesn't need to move anymore, so like a plant, it is planted, and because it needs resources but doesn't need a movement organ or a prediction organ like a brain, it just eats the brain as essentially nutrition?

LLINÁS: Yes that's right, it forms it into some gut, it becomes a bit of gut.

BINGHAM: I've heard people make a joke, by the way, that that's what happens to professors when they get tenure.

LLINÁS: (laughter) To some professors. Right, indeed that is the case. So as you can understand, this is a beautiful biological demonstration of what we're talking about. If you are going to move actively, you need a brain. Now the opposite is also the case. Any animal that moves, however primitive, has a nervous system, and as you know it happened almost as an explosion, in an explosive way, a lot of different types of

animals appeared with a lot of different types of nervous systems. And by the way when you look at neurons, they're almost exactly the same regardless what animal you are. So if you're an octopus, if you're a spider, a fly, if you are a vertebrate, still they have the same neurons, that is the cells that constitute the nervous system, the same channels, similar type of response, so a very interesting, a very deep issue happens. Part of the tissue becomes the nervous system that again generates motricity by activating muscles, has motricity pattern so you can go forwards or backwards or whatever and has a desire to move, intentionality. That is present in all of them.

So yes the brain seems to have evolved, or I believe and many people will agree, as the instrument for motricity, the instrument to move. Now because it is so closely related to prediction and so closely related to intentionality when we make an impossible statement and say you know what, thinking may be nothing else but internalized movement. Why? Because it is through movement that we solve many things. And what is it that the brain basically does ultimately in all of us? What it does is generate premotor acts, inside it generates premotor events, all that we can do as human beings with our brain is activation of motor neurons, that is the only output. I tell my students you only activate muscles or you activate glands. To put it differently, you either move or drool, that's all you can do in life. Its true. Ok so you have this apparatus that defines movement beautifully, that predicts that has all sorts of hypotheses on which to act. So thinking is a premotor act. And therefore we are fundamentally moving animals that move intelligently. The more intelligent our movement, the more intelligent we are as animals.

BINGHAM: Ok now that's, I mean people will immediately say and probably have said to you, well come on there must be more to it than this, we have consciousness, where does consciousness come from and how does it emerge from this description you have of something moving?

LLINÁS: Yeah ok, but that's a slightly different story. We can go there if you like right now, but we probably should define to make sure that the initial statement which is, we are there to move, the system is there to organize movement is a possibly valid hypothesis. The next point you make is very important because it has to do with intentionality. If you again, as I said before, if you have the ability to move but you don't use it, you don't move. So why would you move? What is the reason why you start your movements? Well, to many schools of thought, the most well-known, the most agreed to is the fact that these neurons have intrinsic properties like the heart that is continuously beating and then if you happen to be, let's say a shark, you have to be able to move in order to breathe, so movement is part of existing. In other animals you can breathe without actually having to displace yourself like we do, we just move our chest and bring air in and out, but we can be sitting as we are now without necessarily walking. So now what is this intentionality about? In the intentionality seems to be something relating to our ability to have a perception of things, that is, to feel. Why do you want to move? Because I feel like moving.

BINGHAM: But I would argue that isn't there something more fundamental there which is that your system, your entire system, one of the things its doing in terms of homeostasis or in terms in energy use is always to maintain itself in a viable energetic state? So the whole system at some point says things like "I'm hungry", or...

LLINÁS: No, no, it doesn't say you're hungry. We say we are hungry.

BINGHAM: Ah, we say.

LLINÁS: And this is exactly the point I am going to. In order to breathe, in order to be a plant, you don't have to say here, I am a plant doing nothing. It doesn't come to that, it simply is. The hope to move for a plant would be a disaster, a tragedy. Here I am a plant. No, only when the possibility to move is there should we ask should I or should I not. So mind-ness is related to something, well this is going to be a little shock and say if you ask me, why not, what is all of this come from? These feelings and desires and so on? Well, my feeling is that irritability is actually cellular. That is, that among the reasons why it took so long to make cells is that the cells are far deeper than we ever believed they were. Putting it very quickly to the point and then coming back up in steps- if our cells don't feel, we won't. In the same way that if our cells are incapable of contracting, we won't be able to move. Computation can't do it. You need effectors- effectors for motility and effectors for sensation or feelings. Hypothesis: that desire in fact has cellular elements.

So once you have the ability to move, the ability to predict, and intentionality which comes from the fact that the cells are irritable, they have sensing abilities that modify the internal environment, to the point that the sensation, whatever that may be, is an intrinsic property of the cells, then you have a complete system that can of course think, that can fear, that can do all of the things that we characterize as the mind or as thinking or as hoping or whatever.

BINGHAM: So you're talking about a community of cells that each, that interact together, have the capacity to register at any given moment their state and their state is converted eventually into what we would then describe as a feeling like "I am hungry" or "I am attracted to" or ...

LLINÁS: All of those things that represent the descriptions of possible movements, which is what thinking is, internalized movement, right?

BINGHAM: Ok now you're talking about whole organisms here, you're talking about eventually consciousness; you're talking about things that we'll get onto like qualia, the sense of what it is to feel like something. But you didn't start there; you started with very basic information at the cellular level. I mean your training itself. Let's move forward from when you were four. You've been, you've had this wondrous

experience of living in a house where strange things happen and you have somebody, luckily, who can explain them or begin to explain them to you. So that I assume motivated you to go and find out more. And so that then takes you to university right?

LLINÁS: It takes me to the medical school. I go to the medical school knowing that I would learn more about the nervous system and how the nervous system is supported and so on and so forth. By now I am fully aware that we are just brain and the body is there to decide or to do whatever the brain requires the body to do. It is the great carrier of the brain, so get inside there for the brain and so on and so forth. It is a little bit of a brain-related skewed view but its true. I mean people without brains, not necessarily very healthy. I can imagine brains in a vat so I can imagine that I could conceive of somebody dreaming or thinking whatever, when that would happen. So this system is a little bit asymmetrical. So I wanted to learn about the nervous system, you know, anatomy, physiology, biology, pathology, and so on and so forth. Interesting.

BINGHAM: Where are you now? You're now in Columbia right?

LLINÁS: I'm still in Columbia, I go to a very good school, high school, the likes of which I've never seen since that time. Really superb. I mean... incredible. Outstanding.

BINGHAM: In that the teachers were particularly outstanding or..

LLINÁS: They were very outstanding. It is tragic in some ways because my teachers were people who fled Europe during the war. So my professor of philosophy was Mr. José Pratt, one of the most important theoreticians, social theoreticians in Spain. He taught me philosophy when I was 14 years old. (???) who used to work in Cavendish laboratory taught me physics and math. Mr. (???) who was one of the professors of chemistry in France during the war taught me chemistry. So yes well, I cannot, I tell you, I cannot thank enough, Providence or the ability, whatever it is to produce this beautiful set of people who should not be teaching students of my age how to think.

BINGHAM: Or perhaps they should.

LLINÁS: Please, wait ok that's another story. Let me tell you. I am really a bit nuts in that direction in the sense that I find so sad that we go to school and our brains get ruined by our teaching systems. People teach you things instead of teaching you concepts. You have to learn the tributaries to rivers that you can look up in a book. You are wasting time and memory with things that would have to be an idiot not to be able to memorize. But you can take a photograph of it so how is it possible to spend so much time being non-educated, wasting prime time learning things that have no use at all to you. In fact when I know this is when I see people and I ask them do you remember geometry, do you remember geography, do you remember these things?

And they say no! We don't remember any of that! And this is almost universal. You know the people who taught you geometry didn't like geometry, so they didn't teach you geometry. I remember my geometry. I remember, they were taught by people who loved the ideas and would demonstrate things; there wasn't a pensus you have to pass. But we're getting off the subject a bit.

BINGHAM: Not really, but...

LLINÁS: But so I had a very lovely education. I was far from being a brilliant student. I simply did what I wanted to do, passed ok and so on and so forth. I already had spin toward things I wanted to do so... but anyhow. They were kind and supportive. I went to a good medical school. In the second year of medical school, I told my father that I wanted to understand Communism better.

BINGHAM: Communism.

LLINÁS: Yeah and I wanted to learn physiology. So he said ok, so you want to go to Vienna to a youth peace movement? Fine. Here's your ticket and you're going to go by and look at the physiology department in Zurich that Professor Hess, Nobel Prize winner of 1946, is the head of. Yes fine. Go with peace and come in one piece if you can. So fine, I learned very quickly that Communism wasn't what I thought it was, I went to these people and said what shall we talk about, the freedom of thinking and all of that and he said don't use that, how much money can you generate for us please. So I said listen, I thought the answer was something like, we have enough theoreticians, thank you, can you help us or what? So thank you very much, I'm going to go to the physiology department and that was it. Physiology, if you were kind of interested, and I learned some physiology at that point, came back to Columbia, told my father that Communism wasn't what I was expecting, and he was very happy and said it takes generally a little longer for people to realize but I'm happy for you. So you know the old story, if you are not a communist when you are 16, you have no heart. If you are communist when you are 20 you have no brains. That was the statement at that time. We know now it's a bit complicated, but it was presented at that time. So continue. So yes I had some early electrophysiology experience and it was very lovely, it was stimulation of the brains of animals and changing their behavior and so on and the idea was incredible, which is you can change the behavior of an animal and make them have rage, make them be docile or make them fall asleep by electrical stimulation. So somehow the behavior was modulatable by electrical currents.

BINGHAM: Ok now I'm thinking of again, going back to 4 when you see somebody having some form of what apparently was some form of a seizure which was electrical activity. You gave a lecture yesterday and today in which you showed somebody receiving electrical stimulation and a dystonia, an inability to move. So there's a sort of interesting full circle there.

LLINÁS: Right absolutely. In fact, that's very interesting you noticed. Yes I've said that many times. I remember being completely moved by the fact that you have this animal lying there be friendly or whatever and you stimulate, immediately the pupils get big and the response took 2 or 3 seconds and then the animal would do 2 or 3 things, one of them- he would attack something or he would produce this incredible sound, this very prolonged vocalization, that was deeply moving because it was coming from deep in the.. it was an expression of total desolation almost. It was a cry; you've seen animals do that. The other possibility is that, you repeat this event many times and one of these three things would happen- either the animal would attack, it would vocalize, or it would have an epileptic seizure and then it would be fine. So somehow having activated a whole bunch of neurons, there are particular things that the system can do with this activated bunch of cells and depending where you activate and what part of the brain you stimulate, it would have this kind of response that I'm telling you or in other cases the animal would simply go to sleep. So you turn on the sleep center. So beautifully, you can address mind properties with electrodes.

BINGHAM: Now what do you mean by mind? In this book you specifically talk about the "mind-ness" state?

LLINÁS: Ok now I both like and dislike deeply the term "mind". The term "mind" somehow suggests that there is something separable from the brain that lives that has its own structure, its own existence.

BINGHAM: Well Paul Bloom has this phrase, "natural born dualist" based on the old, Descartes' notion because it feels that way; it feels as though there's a driver in there, a separate entity.

LLINÁS: Yes, it feels like it, but I don't think it is actually there. I'll tell you a story a little bit as to how I've finally seriously got rid of it in my case, directly. I got rid of it to begin with by simply thinking about it. The question was, when you study neurology and study psychiatry and you're doing surgery and so on, you find if you anesthetize, here's the story in principle. You open somebody's head, you put anesthetic. You find that the mind is soluble in local anesthetic. Isn't that what's going on here, what is it that we do when we do local anesthetic? What happens when you anesthetize the cells? You're blocking certain channels that prevent certain electrical activity from happening. So from everything you know, you say somehow electrical activity is deeply and directly related to movement, feelings, or the total sum of which we can call the mind. Mind-state is simply a particular function of events happening in someone's brain that has certain components- has a prediction component, it has a component that has to do with possible movement, it has a component to do with intention. So I could say, mind-states are states that have 3 components as defined in the way that I just mentioned.

So basically then we have an entity that can organize and move, that has as its- this is a different point of view than many people have that I will say very carefully- Many people think of humans and animals to be mostly driven by reward. I do this thing so that I can get something back. I think that is wrong. I think you do things because you have a drive to do things, sometimes even if it's bad for you or if it hurts you, you will still do it. The intention, the drive with which there is nothing, I don't think is just a product or in fact requires anything to do with being somehow given a prize for doing it. You will say, why do you scale the mountain? Because I feel good. Nonsense. Idiocy. Dolt. You have no choice. That is the kind of animal you are and that is the beauty of it all. You can always say, because I love it, or I do it because its there, which is not a description of anything. You have no choice, the system has as one of its properties, the pull to do things, to be active, to look, and you can see how this would be a very important selection principle. Animals that explore, animals that move, are the much likeliest possibility to survive than animals that sit. So that is the answer to your initial situation. What do I mean by mind? I mean internal state of the brain. Definable. Somebody tells me you can't define the mind. And the answer is nonsense. Now you say free will- how do you define free will? But I can tell you I define free will as those activities that happen that the brain know are about to happen.

BINGHAM: Can you say that again? Because you've just been talking about what you said was not necessarily a generally accepted view, that there are certain drives, can I use the word innate?

LLINÁS: Of course

BINGHAM: Which implies an almost deterministic view of things, which makes the whole concept of free will a little bit difficult to explain.

LLINÁS: Yeah well, two points there. The fact that it may be a set of fixed action patterns does not mean it's completely deterministic in the sense that while the pattern of movement may be very similar, its never going to be same again ever. So all you're doing is defining the boundaries of the possible movement you are going to make or the drive you are going to make. Determinism and free will, well that's something else. I understand that free will does not exist; I understand that it is the only rational way to relate to each other, that is to assume that it does, although we deeply know that it doesn't. Now the question you may ask me is how do you know? And the answer is, well, I did an actually lovely experiment on myself. It was extraordinary really. There is an instrument used in neurology called a magnetic stimulator- transcranial magnetic stimulation is something you can do. Well I...

BINGHAM: It consists of... What actually happens to you?

LLINÁS: Well yeah, its an instrument that has a coil that you put next to the top of the head and you pass a current such that a big magnetic field is generated that activates the brain directly, without necessary to open the thing. So if you get one of these coils and you put it on top of the head, you can generate a movement. You put it in the back, you see a light, so you can stimulate different parts of the brain and have a feeling of to what happens when you activate the brain directly without, in quotes, you doing it. This of course is a strange way of talking but that's how we talk. So I decide to put it on the top of the head where I consider to be the motor cortex and stimulate it and find a good spot where my foot on the right side would move inwards. It was *pop* no problem. And we did it several times and I tell my colleague, I know anatomy, I know physiology, I can tell you I'm cheating. Put the stimulus and then I move, I feel it, I'm moving it. And he said well, you know, there's no way to really know. I said, I'll tell you how I know. I feel it, but stimulate and I'll move the foot outwards. I am now going to do that, so I stimulate and the foot moves inwards again. So I said, well what happens? I said but I changed my mind. Do it again. So I do it half a dozen times.

BINGHAM: And it always moves inwards?

LLINÁS: Always. So I said, oh my god, I can't tell the difference between the activity from the outside and what I consider to be a voluntary movement. If I know that it is going to happen, then I think I did it, because I now understand this free will stuff and this volition stuff. Volition is what's happening somewhere else in the brain, I know about and therefore I decide that I did it. It happens in science as well. You actually take possession of something that doesn't belong to you.

BINGHAM: So what was your, so you're saying because there's this straight-forward linkage between the stimulation and the foot moving inward, right and that's going to happen every time- even if you will yourself to move it out and it still moves in, are you saying that you never less thought your sensation was of having moved it out?

LLINÁS: No! The sensation is different- it was I who did it.

BINGHAM: Even though I was moving it in.

LLINÁS: It moved it in and the sensation is, well I moved it in. I could not, my system, I could not have a feeling different to what I would have had had I moved it inwards. So I want to move it outwards, when I feel the stimulus, I move it outwards and move it inwards. Did you feel that there was a problem? No I didn't feel there was a problem, I moved it inwards! But you thought, you decided you were going to move it outwards! Yes, but I moved it inwards. And then you think and you realize that you are saying it after the fact that you moved it inwards because it moved it in the inwardly manner and you knew this was going to happen so you take possession of it. In other words, free will is knowing what you are going to do, that's all. Not

necessarily willing it. Sorry. Now for other reasons, you may find that the rest of the nervous system other than what it wills basically wants to do that, you properly educate it; you think it's the most intelligent thing to do and so on. But the feeling that it's you who's doing it is a simplification. It is not you who's doing it, it is many cells deciding to do it.

BINGHAM: Does this... I mean at the beginning of the book you talk about Sherrington, Sir Charles Sherrington, a very famous neuroscientist who coined the word synapse, whose student was Sir John Eccles, with whom you studied, so you have this whole tradition. Sherrington gave some lectures in 1932, 37 perhaps it was, I can't remember exactly. The Gifford lectures, very famous, now known as "Man on his Nature", "Man and his Nature", yes. You say in your preface here that, I quote, "Sherrington hinted that if human beings ever came face to face with their own true natures, that knowledge might trigger the demise of human civilization." It's a pretty large thing to say, what did you mean by that?

LLINÁS: Well I didn't say that. I was simply paraphrasing something that Sherrington said.

BINGHAM: What was your interpretation?

LLINÁS: My interpretation is he believed that to be the case, that somehow in order for us to respect each other, in order for us to love each other, in order for us to be kind, to be civil and so on, there had to be a mystery type component to the whole thing. That if we were to really understand why we love and what we hate and why we do what we do, that somehow the drive, somehow that which makes us human would disappear because somehow humanity is fed by the mysterious and by the unknowable.

BINGHAM: Now that seems to be antithetical to what you've been saying and what you've been doing all your life which is to reveal as much as possible, to demystify.

LLINÁS: That's right, so as I say in the book, I find that surprising. I said, I would in fact consider the opposite view which is the more you learn about the nature of what we are, the more we would like each other and the more we would understand each other. Mostly what we do is not so much hate each other. What we mostly do is not understand each other. So indeed if I, I think if I could really understand another human being as well as physically possible, let's say, that individual becomes more interesting to me rather than less interesting. At least this happens with everything else that I've done in life and probably happens to most people and happens for sure to scientists. That the more they understand something, the more they like it, the more they love it, the more they understand it, and there's an incredible feeling of, not of possession, but of being a part of something when you understand it. So I'd have to disagree deeply with Sherrington's feeling.

BINGHAM: We've had a couple of meetings here discussing things like science and religion and as you know, there are many scientists who have an enormous trouble making the kind of leap that you're talking about there, that they in fact would like to retain the sense of there being some ineffable force outside science, outside rationality and so on. Do you have any thoughts about religion, what happens when people come to an audience and ask you about these sorts of issues?

LLINÁS: Well I mentioned that I am not religious, that in my family, my father was not very religious but my mother was and discussing with my mother, Rodolfo, why aren't you religious? And the answer is well, I can't understand it. I don't know what you're talking about. I mean, I understand the words, but when I think about, let's say God, and I look you in the face and you say God would help me, it looks like what one is a friend in a high place. You want someone to ask favors to. It is what you want that you love; you can't love an entity you don't see or understand, so what is this? And fortunately for me, something appeared and it was a very difficult but very small book by one Baruch Spinoza who said so very beautifully, exactly what one was thinking, that is that we are not made by the image and resemblance of God, but rather but God is made by our image and resemblance. For instance, I was always surprised that God would require me to pray about something that I needed, knowing that He's supposed to know everything, so therefore, he must know what I need and want, so why should I have to ask? Not very friendly. Why do I have to pray? Why do I have to say You are great and I am small? Why? It looks like a relation between a servant and a patron. The answer is He is very powerful and you are nothing. But ok I understand that, but I don't think I agree with it. You know, so this is the initial steps as a young person, I don't understand this stuff. You go to mass because if you don't go to mass, you go to hell or something. It seems to me like a political event is happening here and somebody has found a way to sort of organize people in a particular way. So that was basically the beginning of it and then you of course understand that in fact you were right. To me, it was right, understanding that if there were to be a God, it wouldn't be anything like this humanoid that many people believe exist, the owner and creator and so on of these things.

BINGHAM: On a larger scale though, to go back to Sherrington's point, if you exclude religion from it and so on, do you have a sense, this need for something.. Do you have any sense of an explanation for why people seem to have this need for the mysterious?

LLINÁS: Hmm, I think its actually a strange romantic view. The thoughts that come to mind are rather strange but let me tell you, it's a little bit like Groucho Marx saying I would never belong to a club being so low that I could be a member of, so no, I don't think very highly of myself. I really don't want to understand because if I understand its not really very important. In fact, many great scientists said, you know, if there is

no extra life or whatever, its nothing. So it is a bit not wanting to face the fact that we are ok as we are and we can forgive ourselves for being.

BINGHAM: So in everything you do, the work you've done at the cellular level all the way up to using MEG and being able to quite clearly show that people's systems are moved by electricity and so on and so forth, you find no evidence of anything other than, as you said at the beginning of your talk, that basically brains are us. That's basically what you were talking about.

LLINÁS: Imagine how wonderful it is. We are our brains. This to be the source of almost all type of felicity. It's an honorable state to be in, to know that you are what you are.

BINGHAM: If you hadn't been a neuroscientist, what would you have wanted to do instead?

LLINÁS: Well I like astronomy and observatory and so on, so I probably would have gone for something like that, another type of science. I am probably not a big enough monkey to be a serious contender for physical things, so I did fence but I didn't think it was a great future in being a foil champion or something like that. I didn't think that professional sports were for me really. Um money is interesting but not that interesting.

BINGHAM: Are there any discoveries you wish you had made, would have liked to have made? Beyond what you've done.

LLINÁS: No. Oh, do I wish it was I who discovered something? Oh yes. I'm completely in love and fascinated by science and every time something new occurs, I have both a feeling of happiness for science, of admiration for the person who did it, and a certain degree of jealousy I think. I wish it was I who had done it, which means I really liked it.

BINGHAM: What about this new work you've been doing, using... Can you explain this new work you've been doing using nanowires? "Nano" of course is very much a buzz phrase and perhaps you could explain that we're just talking about extremely small technology here and how it works and so on?

LLINÁS: It is something that is the obvious next step in the conversation we've been having. We were saying look, the nervous system evolved to move, intelligent language, and all the things are pre-motor events that allow you to then move intelligently. Moving intelligence is what we do at this point and we extend that. We also know these things can be modulated by electrical means. You can stimulate, you can move your foot, you can stimulate and get someone who has a disease to not have the disease anymore and so on. So the system is amenable to direct interaction with

the external world by means other than nerves. Comma oh my god, closed parentheses, really. And I say yeah. The problem is that the brain is guarded by bone. I say in the book we have an exoskeleton when we talk about the brain. The rest, the muscles are out and so on, so ok. If a) the brain were to, if the cranium were to be transparent, we could see the activity of the brain, instead of looking at people's faces, you would look at people's brains and say don't think that. You could see the patterns and say no, no, don't take it like that. The same thing happens when somebody tells you that they're not agreeing with you.

Imagine that in addition to doing like that, you could say well what if I actually communicate with you directly so we don't have to go through all this blabbering or this talking and I'll tell you exactly how I feel. How could I do it in principle? Well I could go directly to the brain. The problem is, oh my god, but you have to then penetrate this bone. So thinking about how could we do it, is well, the brain is full of holes, don't make any new ones. And what are the holes I'm thinking about? The vascular system. So imagine. The blood vessels, right. Imagine yourself becoming very small in this beautiful whole film- science fiction, into the vessels and you go into the brain. Where can you go? Anywhere. The brain is completely vascularized. It's full of these vessels and they occur every 15 microns, it's a 3-dimensional scaffolding that goes everywhere. And then the question is, don't go to the brain through the outside, go to the brain through the inside. Why not put a wire up to anywhere you want in the brain and try to record or stimulate or both. But it has to be a very thin wire because you don't want it to bother circulation. It has to be of such material that it's not recognized by the body as being there. Can this be done? The answer is yeah, there are ways to protect the wire from being...

BINGHAM: You're right, this does sound like science fiction and the utility would be what?

LLINÁS: The utility would be.... The utility would be as follows. At this moment we are getting to about a 30 nanometer wire. It is a third of a micron- a micron being very small- thousandths of a millimeter. You can put several hundred in the diameter of a single hair. Ok so you float this thing, say you want to do more than one, you want to do ten or a hundred or a thousand or ten thousand or however many, so you can wire the brain from the inside. What can you do? Two things, you can record and you can stimulate. Ok so you have something in front of you about your brain or in front of you about somebody else's brain, heaven forbid, with the ability to address the brain. What is the first thing you do? Well you probably instead of doing electrical stimulation of the top, you'll do it to the vessel.

Now is this done? The answer is, it is done every day in neurosurgery for other reasons. The people who do that are called interventional neuroradiologists and they put in things that go around and let go little objects that would close a vessel that has an aneurysm or something. You correct, this is things that people know how to do

very well and I have many friends who are neuroradiologists. You say, ok can you put this thing and please I'd like to have my visual cortex wired. Yeah sure. Put it in. You put a little ball of these wires which then on touching fluid begin to slowly move out and of course you wire part of the brain. They are so small they are not going to impede circulation; they are not going to produce coagulation. They are simply not going to be recognized as being there.

BINGHAM: Now I assume this is primarily for repair rather than recreation, right?

LLINÁS: Why do you think that?

BINGHAM: Because people usually get grants for fixing things.

LLINÁS: Of course. Well yes you can repair things. Or you can have man-machine interface. Seriously for the first time, seriously seriously. You need to remember the name of all the people that you know so you have a little bank in principle might be able to whisper to you the names of the people whose names you need to remember. You may buy a good program to learn or play chess. There are many things that you can do once you have direct access to the brain.

BINGHAM: This is taking PDA to extremes isn't it?

LLINÁS: But wait, this is just the beginning! If you really love somebody, can you imagine connecting with the person, seriously? Can you imagine it? Yeah you could. Ok, what about a bunch of people? The rest doesn't have to be set, because you see it is obvious. If you have an entry into the brain directly that you can read from and put into, input and output, you're now not limited by your senses.

BINGHAM: Now obviously this has been said to you before, but this does begin to sound a little bit like an Aldous Huxley novel.

LLINÁS: Excuse me here. This stuff is not a novel! The fact is that you can stimulate and you can record. It hasn't been done yet, it has been done in frogs but we know once you have the thought, once you have the idea, once the idea is out, you know it becomes inevitable. There are too many reasons why this could be a very good idea. Now like every other idea it has to make, it has to be made sure that it is not misused. And this is the ethics component that is so difficult and so complicated. The answer is don't do that because you're going to make an impossible change. At the same time somebody says excuse me, I'm paralyzed, I would love to be able to move, why are you so mean? Why is it you don't help my son who has this problem or my daughter has this schizophrenic, has depression, has whatever. So yes, the medical part will come first.

The next thing is, well, I would like to be able to have an artificial arm that I could activate directly. Suddenly the arm is.. it would be possible to have a bunch of people connected to each other such that they operate, let's say as a wolf pack. They are a group that anybody is in trouble, everybody immediately knows, there is no question of making noises or anything. Suddenly you have a collective group that can protect each other much better than you can as a single individual. Is saving lives important? Blah blah blah blah and so on and so forth. So what is the limit? Well individual intelligence. So, you know, its on the table, it would be done or not done, whatever, but we know that it can be done and we know what it means, so some people will think of it in horror, other people will think of it as a brand new world.

BINGHAM: So the important thing is that we have the information there so that people can make those decisions. Let me ask you a couple of questions- we have to close fairly shortly, but let me ask you a couple of other questions. There's each year, the literary agent John Brockman asks people a question and a lot of people write in and give answers. This year's question was what are you optimistic about? And I ask you the same question.

LLINÁS: You know what I think life is really incredible. I'm optimistic about human nature. I believe, especially in America, we've been historically in all kinds of trouble. I know very few countries that are as capable of jumping out of almost anything as we are. So when I look at my children and look at my grandchildren and people say they would have a difficult life because there is no, they are packed with brains. The sad thing would be if we would cease to exist. I don't see that happening simply because our brain is so resourceful.

BINGHAM: Is there anybody...?

LLINÁS: So the answer: being alive is what I'm so very positive and very optimistic about. Life itself, I think is absolutely it.

BINGHAM: Now your children, you mentioned children. You have 2 sons?

LLINÁS: Two sons, yes.

BINGHAM: And they have become?

LLINÁS: They are both physicians, they are fourth generation physicians now. One is a neuro-ophthalmologist and the other is a neurologist.

BINGHAM: So this is a long family tradition here.

LLINÁS: Everything from the neck up for everybody, don't mess up with these lower organs.

BINGHAM: So you have a great deal to owe to your grandfather there for this.

LLINÁS: Well yeah, it is in fact. One thing that I learned from him was how important it was to be treated as human being when you are a child. The other thing was the ability- he was a renowned teacher like my father was a renowned teacher. They would fill rooms whenever they taught anything because they were extraordinarily clear in exposition. Excuse me for a bit, this is something I always remember, I remember asking my grandfather, now how is it that a plane, an entity as heavy as a plane, can fly? I've asked people and it's very mysterious and he says no, it's extraordinarily simple. The plane, consider the plane is just a knife, which in one plane cuts the air in up and down and another knife in the back cuts from left to right like a knife going through butter. It has to have a certain speed so the air becomes a little denser. So it has these two knives and then it screws itself in the air with something called a propeller. I knew what a screw looked like. And that was it! Whatever else I've learned, including learning to fly- I have my own plane, was basically the two sentences or three sentences because that was it. It's really not more complicated than that. There's a lot of details. So yes, the ability to have simplicity at the other side of complexity, that's what one was given and that's what one hopes to give when one teaches.

BINGHAM: Is there anybody that you'd have, thinking about great teachers- is there anybody you would have liked, historically, would have liked to have had a conversation with? You actually had the chance with some conversations with some great people.

LLINÁS: Well no, I mean but I did. I mean, Feynman or Eccles, of course, and mathematicians, Al Gelfond and Thom and whatever, many many interesting people- Wheeler and so on, sure. People that I would love to have been able to have a good conversation with- well I would wonder what a conversation with Wittgenstein would be like. I don't know that it would be possible, but I wonder. Or with Turing would be like, or with Euler would be like.

BINGHAM: So you're very into mathematicians, logicians.

LLINÁS: Well these, the people that somehow have managed to have the maximum simplicity, have the complexity. So of course, they are the demi-gods in the sense of having understood seriously by excluding things which is simplicity after complexity.

BINGHAM: Do you read much philosophy? Do you like...?

LLINÁS: Oh yes, yes, the usual components in high school, I had good philosophers which I mentioned. And well, I read my colleagues in neurophilosophy these days, the Churchlands I read, of course.

BINGHAM: But do you think that's a way in which we're in fact going, that injection of more neuroscience into this is essential to a clearer understanding of some of these major issues like ethics?

LLINÁS: What I find that is very nice about, I have problems with philosophers, my wife is a philosopher, I don't have problems with her by the way. I have problems with philosophers and I also immensely admire, have a lovely time with them. The nice things about philosophers is the fact that they language, generally, very clearly. They define the terms very nicely, a bit like mathematicians do, which is why. The problem that I have with philosophers and with most neurophilosophers, there are some that are ok, but some of them are not, what they love to do is to analyze the problems but they are not interested in solving any. The usual story that you've heard probably many times- Russell's definition of a philosopher. You remember he defined the philosopher as this person who being standing in a corner is approached by somebody on a bicycle who asks him, sir, where is London? And the philosopher says where, where, where... is, is... London. Yes, I don't know. As long as you ask it properly its ok, the answer doesn't matter.

BINGHAM: I think on that note we'll close. Thank you so much, Rodolfo Llinás.

LLINÁS: My pleasure, thank you for having me.