SEARCHING

OUR QUEST FOR MEANING
IN THE AGE OF SCIENCE

UNDERWRITER ANNOUNCEMENT [00:15]

ANNOUNCER: This program was made possible in part by the John Templeton Foundation. The Templeton Foundation supports academic research and civil dialog on the deepest and most perplexing questions facing humankind.

PARTS 2 AND 3 RECAP [00:15]

ALAN LIGHTMAN: Previously on SEARCHING… As a scientist, I believe that we're made of atoms and molecules and nothing more. But could that cosmic feeling I had that night looking up at the stars be understood by neuroscience? What about falling in love? Our science and technology attempt to understand the cosmos… but we humans ourselves are as complex as a galaxy. With his telescope, Galileo showed that even the heavens are impermanent. And yet we long for permanence. Philosophers and faith leaders wrestle with the mystery of consciousness. Will advanced androids be conscious? And how should we relate to them? In terms of powers of ten, we humans are almost exactly between an atom and a star. That's where we fit in the physical universe. But where do we fit in the moral universe? With our science and technology, we're evolving beyond biology into something part human and part machine. What aspects of humanity should we try to preserve as Homo sapiens tranforms into… "Homo Techno"?

ALAN'S CONVERSATION WITH ROBERT DESIMONE [02:49]

ALAN: I've been exploring the smallest and the largest things out there in the universe. But what about our inner world? What about the universe of human perception, consciousness, self-awareness? Everything we know about the outer world is filtered by that inner world. And it all takes place inside the brain, the 100 billion neurons and the trillions of connections between them. There are about as many neurons in each of our brains, as stars in the Milky Way Galaxy. Fortunately, today, we have better tools to understand brains than ever before.

ROBERT DESIMONE: Well, in my little museum here, we have the history of brain stimulation.

ALAN: Today's tools, like the fMRI machine, are very different.

ROBERT: You could have these various devices that could pass currents through the head or what other part of the body, ailed you.

Also in my, in my museum here, I have the original tools that were used for lobotomies. Unfortunately it was a very abused treatment and knock it in through the skull and then rotate it around. It's really barbaric.

ALAN: Fortunately, my time in the M-E-G was non-invasive!

I first found out about you and your work, in respect to your work on attention and how with the zillions of inputs into our brain every second, how the brain decides to pay attention to some of them and ignore others.

ROBERT: Attention, I think is, is a tractable problem in neuroscience, as opposed to, let's say, consciousness right now, which is a much more difficult problem. But compared to consciousness, attention is, seems like it's more tractable, but it has a profound impact on our conscious awareness.

ALAN: When we're paying attention to something, is there any particular manifestation in the neurons themselves?

ROBERT: Once the subject starts attending to something, then you see the influences of all the distracting stuff goes down and then there's a more pure signal related to what you're attending to. And then we also find that, for those neurons processing that attended information, they tend to synchronize their activity with each other more than they do when they have these signals from the unattended stimuli. So, there's a synchrony of activity in the brain that's also a signature of attention.

ALAN: I'm looking at this very interesting group of objects here. You've got some soda cans. You've got something that looks like metronomes. Is that part of your lab equipment? Did you have to pay a lot of money for that equipment? Of course, I had to ask Professor Desimone to set this fancy scientific instrument in motion.

ROBERT: I'm going to, um… get the metronomes going…

ALAN: And they're all moving at random.

ROBERT: Right. So, they're... they're just.... they're just random. And they won't synchronize because they can't influence each other. It's like, they're anatomically disconnected. But, when I put this board on the soda cans... Over time...

ALAN: So, they're communicating with each other...

ROBERT: You can see that... Yeah.

ALAN: And now they come into synchrony.

ROBERT: I use it for a demonstration because I think there's a common tendency to think that if the neurons in our brain are synchronizing their activity, maybe there's some mysterious internal clock that synchronizes this, you know, some master synchronizer. And I think it's more a property of the bio-physical nature of neurons, and their anatomical connectivity that will support these oscillations. And the thing with the metronomes is that you can demonstrate this in natural oscillators, that they can "mysteriously" synchronize their activity.

ALAN: I've always wondered how a gooey mass of neurons and tissues can produce this extraordinary, unique, first person experience of consciousness. So do you think that we will ever understand what consciousness is and how it emerges from the brain?

ROBERT: Well, I guess I'm a reductionist and I'm a strong believer that our brains will eventually be understood, and that understanding will help us to understand things like consciousness and so on.

ALAN: Do you think that we will ever have a theory of consciousness akin to what the physicists talk about a "Theory Of Everything" where it's pretty much a complete theory of consciousness?

ROBERT: I personally believe that we will. I can't say it's gonna be next year but I think we will eventually get to that point. I mean, I think in brain science, we are at the point where the astronomers were when the telescope was invented. That all of a sudden all this new technology we have for observing and measuring brain activity is giving us exponential growth in what we know about the brain, and our theories are trying to catch up, because we have a lot more data than we have good understanding. It's not gonna be my generation, but I think it maybe that next generation.

ALAN: If we were able to understand the brain fully, as fully as a reductionist could understand the brain, and you took the brains of two different people and you put them in a computer or whatever, so, that you had total information about each brain. Do you think that you could predict whether those two people would fall in love or not?

ROBERT: Whoa!

Ha ha ha ha! I see, I didn't predict that question. Ha ha ha! I do think that if you had enough data from the brains of people who have fallen in love that you could make predictions based on the state of activity in those brains. Yeah. I don't see anything that's inherently impossible about that. Sure.

ALAN: Is there anything that you would not want a computer to predict? I mean, speaking for myself, I wouldn't want a computer predicting who I was gonna fall in love with.

ROBERT: And why is that?

BOTH: Ha ha ha!

ROBERT: It'd save you a lot of trouble!

ALAN: I like to think that I have free will.

ROBERT: Ah, free will! Ha ha ha!

ALAN: So, do we have, do we have free will?

ROBERT: Well, I would say now, the easy answer is that our predictive models are just probabilistic. What it would say is that there's a 70% probability you'll fall in love with Mary, and a 40% chance you'll fall in love with Alice and so on, right? And so, that difference between that percentage and a hundred percent is your free will. Now as the systems get better, I guess your free will begins to shrink.

ALAN: I have to say, I don't completely share Professor Desimone's reductionist view of consciousness. But, still, today's neuroscience has amazing capabilities.

Alan to Robert:

If we look at the last few centuries of science, and maybe even just the last century, there have been incredible advances. So, looking at these advances in science, do you think that they have made us bigger or smaller?

ROBERT: I mean… I can only, again, it's my personal view, but I believe they've expanded… Knowledge expands us does, and never restricts us. Knowledge about how we work, how cells work, how life works, to me is opening up such tremendous possibilities. I'm in awe of the possibilities that are in front of us, as opposed to being, you know, constrained by a lack of knowledge, like being in an intellectual prison cell, right? You don't wanna be in a prison cell. You wanna be out in a world that's full of possibilities. And that's what science is giving us. We… tremendous possibilities with the knowledge that we have now and which will only expand.

"ANTS" [11:29]

ALAN: I'm still a bit dizzy from contemplating the billions of neurons in my brain and galaxies, billions of light years away. I think I'll tune in to something simple... like one square inch of the ground. The Buddhists have a concept called "mindfulness": being present in the moment. For a few minutes at least, I'm going to ignore the rush and heave of the world and pay close attention to what's under my feet. In some ways this moment, this single moment, is just as vital as the billions of years of the cosmos. It certainly is for me. And perhaps for that tiny gray-colored insect that has just appeared. It has six legs, antennas, and delicate stripes on its upper back. It must be one of the zillions of nameless animals that inhabit every cubic foot of the biosphere. It slowly crawls along one branch of the micro forest. I wonder where it's trying to get to, or where it came from? It doesn't seem concerned with the Big Bang. It probably isn't searching for meaning either. Maybe you need a big brain for that.

And here's another denizen of this world. It's dragging a centipede along behind it. It's on a mission. "Enjoy the moment," I want to say to it. At times like these, I think eternity may be over-rated. Every moment is a gift if only we can grab on to it. I believe I've managed to stop time... at least, in this one square inch of soil. The world keeps rushing ahead, but somehow I feel restored. I've reconnected with the natural world and with myself. I think that meaning, whatever it is, must be partly found in the moment... even as we yearn for immortality.

REBECCA GOLDSTEIN [14:09]

Over the years, when I've struggled with questions of meaning, I often turn to Rebecca Goldstein. She's a philosopher, and also a novelist. Rebecca once told me that, "Science tells us what is. Philosophy tells us why it matters."

REBECCA GOLDSTEIN: One of the very interesting things about our species is that we want to get our bearings in this world. You know, we sort of come into this world, and basically three large questions that I think is in the nature of every human, to contemplate and to ponder. Which is first of all, where are we, what is this place? Are we one with the universe? Are we matter? Are we something spiritual? We seem to ourselves to be something so much more than mere matter in motion. You know, what are we? Are we one with the universe or not? And then, what are we supposed to do with whatever it is that we are?

ALAN: So those... those big three questions that you mentioned, they seem related to an overall question of why do we want meaning, why do we search for meaning?

REBECCA: You know, I think it's particularly related to the third question. "What am I supposed to be doing with this life that I have here?" I don't want it to be for nothing.

You know, we, we care terribly about our own survival and our own flourishing, and the survival and flourishing of those who we love and, you know, and the broader community. We want it to be for something, and we know that generations upon generations upon generations have lived their lives, and lived it with all the longing, and all the passion, and all the effort and striving that we have. And they have disappeared into nothingness.

ALAN: And we will be gone as well.

REBECCA: And we will be gone as well.

ALAN: Would we be happier if we weren't beating our breasts searching for meaning?

REBECCA: Umm, we wouldn't be us, we wouldn't be human.

ALAN: Do you think that science, and I guess I'm talking about brain science, neuroscience, psychology, will evolve to the point where we could predict whether two particular people will fall in love?

REBECCA: Right... If you mean, could they look at the... the electrical impulses, and the chemical reactions, the chemical compounds...

ALAN: That's what I mean.

REBECCA: No, I do not. I do not believe that. Even though I think that there is nothing going on in experience, but stuff that's going on in the brain, it's hard to imagine going from that information to... to the experience itself. That's what we call "the hard problem of consciousness." And it's a doozy of a problem. We're waiting for the Galileo of neuroscience to just change the parameters.

ALAN: You said earlier that, prior to the age of science, wherever you define that period, that the universe was "cozier." So, how would you compare that with our conception of the universe today?

REBECCA: It is decidedly uncozy. We're not tucked into bed, all nice and cozy, with a kiss on the forehead, from a loving, all powerful parent. You know, we're the grownups. We should take that responsibility very seriously. But I actually find something extremely inspiring about this view. It doesn't seem to me an occasion for ringing one's hands and "We, we are lost in this great universe that doesn't care about us." Since I do believe that we are physical systems made of matter. We are creatures of matter who want to matter.

ALAN: Well, let me ask you this. After we're gone, and after all life in the universe is gone, what will it have meant? Cause there won't be any consciousness there to ponder meaning?

REBECCA: Right. Why is that time any more important, that time in the future when it's a cold, dead universe? Why is that any more important than right now? Why should I judge now by the standards of that time. I'm going to judge now by the standards of this time, and be wondrously grateful for it. I feel kind of grateful that I got to exist and got to participate in the life of humanity.

LEAD TO "HOMO TECHNO": [18:59]

ALAN: For many of us, it's the birth of a child, the growth of a family, that makes life worth living. But we're more than biological beings, simply surviving from one generation to the next.

Our species is named Homo Sapiens. Sapiens means "wise." Yet in the last century, with our science and technology we've bypassed Darwinian evolution. In the future, will we continue to be wise? Will we still have within us a sense of right and wrong? Compassion? Caring and family? Rebecca and I agree that the material cosmos shows no evidence of caring for us. But we human beings certainly care about one another.

"I AM A MAN" [20:06]

I grew up in Memphis during the Civil Rights era of the 1960's. I have a copy of this famous photograph by Ernest Withers titled "I Am A Man." This photograph was taken on March 28th, 1968, during the sanitation workers' strike in Memphis, a week before Martin Luther King Jr. was assassinated in that same roiling city. The photograph shows a few hundred men gathered on the street in front of the Clayburn Temple for a solidarity march. The men don't appear angry, but they do look totally committed to their cause. And they look proud.

With quiet grace each of them is holding an identical sign, which has just four words, "I Am A Man." When I look at this photograph, I'm reminded that a desire for dignity is part of human nature. I'm also provoked to think about what it means to be a human of any color or creed. What are the qualities of humans that distinguish us from other living creatures on Earth? Do men and women occupy a special place in the cosmos? And what about the future? Where are we headed, we human beings?

We hear a Facetime chime on Alan's phone.

Hey, Ada. Hi, sweetie!

ADA: Hi.

ALAN: With the galloping pace of invention, I don't dare look further than a hundred years ahead. In fact, the future is now. My granddaughter, Ada, grew up with the internet and the smartphone. For her, my image on her screen is simply "Grandfather 2.0"

It's hard to imagine what the world will be like a thousand years from now, or even a hundred years from now. Right under our noses, Homo Sapiens is transitioning into what might be called Homo Techno and the change is happening not over millions of years. It's happening in single human lifetimes. By our own inventions and technology we're modifying our evolution, we're moving beyond biology.

ERIK SORTO [22:53]

Erik Sorto, paralyzed from the neck down during a gang shootout in Los Angeles. He was the first human to have electrodes implanted in the posterior-parietal cortex, the part of the brain where intentions are formed. After two years of recovery and training, he was able to control a robotic arm by thought alone. Years later, the implants were getting corroded, and had to be removed. But Erik has continued as a collaborator in the research, sharing his story and what it means. How far he's come is even more amazing when you witness how each day begins.

ERIK SORTO: My past is very dark. I'm an ex-gang member. And that's the reason I'm in the wheelchair. I had it coming. I wasn't a very good person, when I was able-bodied. I wake up with the help of my caregiver, which is my mom, she dresses me, brushes my teeth. And then with the help of a Hoyer lift, she puts me in the wheelchair.

And then I commute to... to the project.

And I try to prove it to the world that I'm not my past. And that I changed. Did I pay a very high price? Yes, but I'm okay with that. My life is obviously not easy, but I choose to make the best out of it, and try to move forward.

ALAN: When you joined the project to have the brain implants put in, that was a very, very long commitment, five and a half years. Why were you willing to commit so much of your time to that?

ERIK: I knew from the beginning, it was a chance of one, a chance of a lifetime. I knew that much.

ALAN: What did it feel like when you were able to control that robot arm?

ERIK: Pretty amazing. It was amazing. It was, I... it was an out of body experience. I was just... I remember how much joy I had in my life when I first moved the arm.

ALAN: So, we're sitting here with this incredible robotic arm here, uh... which is the one that you used when you had the brain implants.

ERIK: Definitely, yeah.

ALAN: I'm going to... It looks pretty complicated to me. I'm going to try to control it a little bit.

It's gonna take off my nose! So, I'm having trouble with this. Uh... and I understand you control it just by pure thought.

ERIK: Yes, I do.

ALAN: How, how did you do that?

ERIK: I would think about a task... but honestly, it was a lot more easier than, than watching you control the... the arm.

BOTH: Ha ha ha ha!

ALAN: You can see how I was having trouble.

ERIK: Yes, I did see that.

ALAN: Well, when you had this, this implant in your brain, in a way you were part machine.

ERIK: Right.

ALAN: I mean, you weren't just all biology. You were, you were part machine.

ERIK: Yeah. I was part robotic.

ALAN: Did you feel a little bit like you were a cyborg?

ERIK: Sometimes I would laugh and we would joke around with my doctors. I felt a little bit like it, but it, it was funny. Yeah. It was fun.

ALAN: It's possible that in the future, that human beings will have other kinds of implants in their brains, not just for disabilities, but maybe to make them more powerful, like a computer chip that might connect you to the internet.

ERIK: Definitely. I have no doubt. That's gonna, that's coming. That's coming next.

ALAN: What do you think about the fact that you will have played a part in that?

ERIK: It's an honor. Yeah. It's an honor. And I can't wait to see what's next. How I hope I can be a part of it.

ALAN: Did you feel fully human when you had the implants in your head?

ERIK: Yes. I felt few... I felt human.

BOTH: Ha ha ha!

ERIK: Yes.

ALAN: I'll try not to make you laugh. That would use up more oxygen.

ERIK: It's good. Very good. We're okay.

ALAN: What do you think makes us human? I mean, what are the things about us that make us different from say, other animals?

ERIK: The ability to move forward, like... you take what you have and you just... you get it together, right? Like the human spirit, right. And, uh... that's what makes us human. To be able to take what you have, move forward, and within that path you gain tools in life to make your situation even better.

ALAN: I think many of us, uh... are searching for meaning, but we're trying to find something that gives our life purpose, a reason, a reason to be alive. What is it that gives your life meaning now and what gave your life meaning before the accident?

ERIK: You know, before I... I didn't even think I had like a meaning before my injury. I was just trying to survive, just trying to breathe.

ALAN: I mean, we're all going to die at some point. I mean, we know that life is temporary.

ERIK: Okay.

ALAN: Everything is temporary.

ERIK: Okay.

ALAN: Even the stars burn out. What is it that you hope will last about you, about the life that you've lived?

ERIK: I wanna share my story with the world and continue growing as a human being. If I can help somebody gain some sort of independence, be more independent than I ever will be, it was all worth it. That was the whole reason for doing it, in the name of science.

BRIDGE [29:32]

ALAN: What will we humans be, several hundred years from now when we're part flesh and blood, and part machine? My hope and hunch is that we'll still marvel at the night sky. That we'll still have that amazing and mysterious experience of being present in the world. That we'll still fall in love. Even that we will still have fear and anger and jealousies. That we'll still have curiosity about the world, our imaginations and creative abilities. That we'll still have our Galileos and our Albert Einsteins.

EINSTEIN HAUS [30:28]

I thought I'd make a pilgrimage to the apartment... where Albert Einstein lived, on 49 Kramgasse street in Bern, Switzerland. A narrow, winding staircase led up to the apartment, three stories up. In 1905, young Albert lived here with his wife, Mileva, and his one year old son, Hans.

In these small rooms, he figured out his radical theory of time and space. This little apartment seems full of emblems of time. I wonder whether the grandfather clock slowed down when Einstein lived here, or perhaps it sped up. There's a table in the sitting room. I imagined that some of Einstein's atoms might still be here. I wondered what Albert thought, perhaps sitting right here, when he came up with his theory, turning the world upside down.

Did he really believe his calculations? To be able to figure out, by pure thought, that time and space weren't solid, dependable things, but could expand and contract like a slinky. Twenty-six years old! What arrogance! Or guts. Or maybe fascination with the invisible world.

You're sitting at a table, thinking about electricity and magnetism and who knows what else, and suddenly you see underneath it all the planets and the oceans and the sunsets and the embryos curled up in wombs, and ashes to ashes, and you're looking at the countenance of the cosmos. A fierce wind has raged over the land, turning ocean to sky, and sky to ocean. Infinity has been compressed to a dot, and the mountains obey. I tried to imagine that twenty-six year old kid. The majesty, but also the humility. What other worlds lay hidden behind the veil?

Albert's thoughts in those small rooms on 49 Kramgasse eventually led him to predict the existence of waves of gravitational energy traveling through space, shaking up space-time in their wake, like a breeze blowing through wind chimes. Einstein was perhaps the 20th century's most celebrated scientific genius, but he thought that gravitational waves would always be too faint to ever be detected. It took four decades of effort for 21st century science and technology to prove him wrong.

LIGO [33:38]

I'm in the cramped and noisy lab at MIT where much of the early work on LIGO was done. LIGO stands for "Laser Interferometer Gravitational-wave Observatory." LIGO is arguably the most sensitive scientific instrument in the world. And it needs to be, to measure the minuscule movement of masses caused by a passing gravitational wave. But the LIGO story is much more than one of cutting-edge science and technology. It's a human story of hundreds of researchers and years of effort. Let's meet two of them.

RAINER ("RAI") WEISS: When I was a kid, I was fixing radios. I was 16, 17, or something like that. That was fun and great and the wiggling of the needle made the noise, but there was a real problem.

ALAN: So, it sounds like a signal-to-noise problem?

RAI: It was. That's the beginning in.... all my rest of my life is based on improving the signal-to-noise.

ALAN: Another key LIGO scientist grew up half a world away in very different circumstances.

ALAN: I understand that when you were growing up in Pakistan that you fixed bicycles.

NERGIS MAVALVALA: Part of my, my childhood was I inherited a really beat up old bicycle from my much older cousin. Most of the time it didn't work and I never had any money to fix it. So, I forged an arrangement with the local bicycle repair shop where I would repair my own bike there, but in exchange for some of my labor, the bike shop... guy would give me parts for my bike.

ALAN: Could you imagine then that you would be working on lasers with the most advanced gravitational detector in the world?

NERGIS: I couldn't imagine it then and I can hardly believe it now. I had no way of knowing when I was a first year or second year undergraduate that I would go to graduate school at MIT. I would meet Rai Weiss. That I would start working on LIGO.

ALAN: Tell me a little bit about how the idea for LIGO first came about.

RAI: Oh, boy, that's complicated. See, there was gravitation and cosmology at MIT, but not in physics. It was in mathematics. Well, what I knew about general relativity, you could stick in the end of my pinky.

NERGIS: First, we have to talk about what is a gravitational wave... do when it arrives here on the Earth from some distant object. So, as it passes through any region of space, it shrinks and stretches the space-time, or it shrinks and stretches the distances between objects.

RAI: Here was the idea. You take a mass, put it over here. And on that mass, you put a laser. Okay? A laser and a switch for the laser.

NERGIS: So, imagine for a moment that this is a laser, and this is a mirror. I shine my laser beam at this mirror. The mirror reflects the light back. And if I have a really good clock, I would measure the time of travel of that light. If a gravitational wave passed through this region of space-time, the space between the laser and the mirror would change. The light travel time would change.

RAI: So, you measure the time it takes the laser to go from here to there and back again. And that time, once a gravitational wave comes along, and goes between those two masses changes, is a really simple calculation.

NERGIS: Now, it turns out it's not quite so simple, cuz the amount by which the gravitational wave changes any part of space-time is really, really small.

RAI: And I found out to my surprise that if you made the thing big enough, you had to make it big, you know, kilometers big. You had to have really powerful lasers, and you had to not have just one mass, but you had to have two masses.

Alan voice over:

ALAN: Not just two masses but two observatories, one in Louisiana and one far away in Washington state, to rule out local noise as a false detection.

NERGIS: So, in fact, what LIGO does is it uses an L shape detector. So, there's a laser right at the center and it sends the laser beam in two directions. And now instead of measuring the absolute time, it takes for the light to travel from one end to the other, you measure the relative time.

RAI: So, you could subtract one mass and the other and use all the symmetries of the gravitational wave, and exploit everything you knew. You might be able to detect the gravitational wave from a pulsar.

Alan voice over:

ALAN: Pulsars are rapidly rotating neutron stars. They were discovered only in 1967, five years before the first black holes. Both neutron stars and black holes are compact enough and massive enough to produce detectable gravitational waves. But both were completely unknown in 1915, when Einstein predicted that gravitational waves would be too weak to ever be detected. LIGO can measure the relative movement of those two mirrors, several miles apart, to an accuracy of one billionth the width of an atom. That's equivalent to measuring the distance to a nearby star to within the width of a human hair. When Nergis first met Rai, she had her doubts.

NERGIS: When he described to me the precision of the measurement that was needed. I mean, I thought he was completely insane. I thought it was insanity to try to make such a measurement. But then he laid out a way in which it could be done, that was plausible. And then I think the other parts of it was I love the idea of reaching a frontier in precision that hadn't been done before. I love the idea that if we succeeded at that, which is a kind of an experimental triumph, we might be able to see gravitational waves, which have never been seen before.

Alan voice over:

ALAN: But for almost four decades, Rai and his colleagues worked on LIGO without actually knowing whether it would succeed.

Alan to Rai:

What kept you going for so long? Do you get pleasure out of building things?

RAI: Absolutely! Absolutely. And that's of course, what over the years has kept me going in all the different experiments. I kept getting my charge by every time we went back to the lab, things went getting better and better. So, I would spend weekends in the lab, and at night with the students, and we would make things work better and better. Turns out when you build things, it takes time to build them. Then you have to check them. And for me, it was a great pleasure to build them. So, the thing that saved us all is the fact that the experimenters still got pleasure out of what they were doing.

NERGIS: Then there's a second piece to this, which is, is advancing experimental science and technologies. And that's something where the endpoint is so far from where you began in terms of technical capabilities, you know, invention and innovation have to come out of that. And it did.

ALAN: Can you describe the pleasure a little bit more?

RAI: I love to make electronics and, you know, you design the electronics and it doesn't work right away. Yeah, you've built it. You made it and it doesn't do the thing it was supposed to do. Well, that's fun. There's a challenge right there. So, you sit there and stew about it, and all of a sudden, yeah, of course, if I'd done it the other way around this would've worked. And you try it and it works. And then you go out and have a beer with the guys.

NERGIS: Every step of the way we were doing things that were... were meaningful and exciting.

Alan voice over:

ALAN: It had taken millions of dollars and years of effort by hundreds of people. But finally in 2015, an upgraded version of LIGO was ready to be turned on. Testing was still going on when suddenly...

At 5:51 am Eastern time, Monday morning, September 14th, 2015, both detectors in Hanford, Washington and Livingston, Louisiana saw the same signal. Its shape matched computer simulations of what might be seen when two black holes collide.

Alan to Rai:

Do you remember what you thought when you first heard that there'd been a signal detected?

RAI: Obviously, I said, it's a blind injection. What is a blind injection? It was a way of testing the entire system of people doing the data analysis, which is a hundred people easily. And I then began to find out that, no, there was no blind injection. The guys who were gonna do that, weren't even ready to do it yet.

NERGIS: It wasn't this instantaneous, "Aha! We've seen something." It was mostly, you know, "Really? Let's be skeptical." And then as you eliminated the possibilities, I could feel the excitement growing. And I remember that was the moment when, you know, the goosebumps exploded because there we saw it.

Alan voice over:

ALAN: LIGO had detected gravitational waves produced by two black holes colliding 1.3 billion light years away.

DAVID REITZE: Ladies and gentlemen, we… have detected… gravitational waves. We did it!

ALAN: In 2017, Rai Weiss and his colleagues, theorist Kip Thorne, and project director Barry Barish, won the Nobel prize for LIGO, only two years after the first detection of gravitational waves.

Alan to Nergis:

What is the significance of LIGO? I mean, why should we be devoting, 40 years plus, in its development, all of the technology, all of the thousands of people have worked on it? What is the meaning of LIGO?

NERGIS: If we care about understanding where we came from as humans, at some point it's not enough to study history. It's not enough to study archeology, or paleontology. You have to get off the planet. Our history comes from the universe. We were born of the universe. Where does gravitational waves fit into that picture of the universe? It fits in, in a really important and fundamental way, which is these technologies we've developed allow us to observe parts of the universe that don't give off light. Black holes, for example.

Alan voice over:

ALAN: Einstein could not possibly have imagined LIGO just as we cannot possibly imagine the technology of the 23rd century. LIGO has opened up a new view of the heavens, just like Galileo's first telescope had done. Now space-based successors to

LIGO might be able to reach back to mere seconds after the beginning of time and space itself: the Big Bang.

Alan to Nergis:

Well, if we look at the discoveries of science in the last couple of hundred years, do you think we should be amazed, or humbled, or what?

NERGIS: All of it. I think we should be amazed at what we are able to do. We should be humbled by how much more there is to know, and we should be ashamed of how much we screwed up.

BOTH: Ha ha ha!

NERGIS: So, all of it.

Alan voice over:

ALAN: I couldn't help thinking about what kept Rai Weiss going for 40 years on the LIGO project. It was his pleasure and his passion.

We sometimes think of science as a totally disembodied, passsion-less enterprise, objectively exploring the secrets of nature. But science is also a deeply human enterprise. LIGO would simply not have succeeded without the passion and emotional commitment of Rai Weiss, Kip Thorne, Nergis Mavalvala and the many others who worked on the project for decades.

So here's something that I take away from the LIGO story: We shouldn't suppress that human side of ourselves, even as we try to fathom the external, non-human world. Aren't our emotions, our passion part of what drives our curiosity, our desire to know our drive to create in science, in art... and in music?

EMERGENT PHENOMENA [46:47]

Swept away by a haunting melody, falling in love, that unique first-person sensation we call consciousness. How can these extraordinary moments arise from mere matter? How can complex human experiences come from the material neurons in our brains?

In recent years, scientists and others have come to recognize something we call "Emergent Phenomena," the behavior of complex systems that's not evident in their individual parts. A good example is the way that certain groups of fireflies synchronize their flashing. When a bunch of such fireflies first find themselves together on a summer night, each insect flashes at different random times, like blinking Christmas tree lights. But after a minute or so, even without a boss firefly giving orders, all the fireflies have adjusted their bodies so that they flash on and off in synchrony. It's the same when starlings flock in what's called a "Murmuration." No one bird is calling the shots. No pre-determined path is being followed. In fact, you could build similar behavior in a computer. Give the individual particles just a few simple rules and set things in motion and look what happens, a digital murmuration. Such collective behavior cannot be understood by the analysis of a single bird or firefly.

Another example of emergent phenomena is the magnificent structures built by termites, called "termite cathedrals." The cathedrals sometimes have elaborate galleries and chimneys to control air flow, temperature and humidity. Yet where is the master plan? Individual termites, which are blind, cannot perceive even the overall shape of the mound, much less direct its design. Similarly, our human brains, composed of a hundred billion firefly-like neurons, exhibit all kinds of spectacular behavior that can't be explained or predicted in terms of individual neurons.

Atoms transcending atoms, the miraculous from the material.

ATOMS EVERLASTING [49:32]

Our scientific understanding of the universe, of stellar evolution, of how life began, of how we're all made of the same stuff, of how our brains work, is sending us a signal. Perhaps the noise of daily life often mutes that signal. But sometimes, in some special places… the signal is louder than the noise.

When we've evolved into Homo Techno, part human and part machine, will we still feel connected, to each other and to the cosmos?

I'm at the Sphinx Observatory, in the Swiss Alps, not far from the little town of Bern, where Einstein made his discoveries about time and space. At 12,000 feet, in freezing temperatures and gale-force winds, with mountain peaks all around me, I feel very small. In many ways, our discoveries in science have made us smaller. Our planet is not the center of the solar system. Our solar system is not the center of the galaxy. And there are many, many other galaxies, some of them billions of light years away. We're ants.

But in other ways, our discoveries have made us very large. We're ants with big brains. With our machines and our equations, we've peered billions of light years into space. We've discovered how the universe began. And we've learned the material stuff that we're made out of. Yet… what does it all mean?

Where do we fit in this strange place of a universe we find ourselves in? With our science and our art, we try to make sense of it. We human beings, living out our fleeting lives on our one small planet, with infinity on all sides of us.

Seen from outer space, our entire planet is a "pale blue dot," to use Carl Sagan's words.

But that nameless artist painting on that cave wall in France, surely, he or she, was searching for something. In our atom smashers, we search for the smallest things in nature. And with our telescopes, we search for the farthest. Albert Einstein and his new theory of gravity led to Rai Weiss's work in building gravitational wave detectors, all extending the capacity of human beings to explore the world.

Jack Szostak and other biologists are now searching for the origin of life on our planet. And the engineers and medical researchers who restore movement to paralyzed limbs with computer chips planted in our brains, they're part of the inevitable march from Homo Sapiens to Homo Techno.

Earlier, I said that if I could follow the atoms of my body backwards in time, I'd find that those atoms, those exact atoms, originated in particular stars.

Now let me now imagine following my atoms forwards in time.

A hundred years from now, even a thousand years from now, my atoms will remain. Those atoms will not know where they came from, but they will have been mine.

If I could label each of my atoms at this moment, imprint each one with my birth date and name, somebody could follow them for the next thousand years as they floated in air, mixed with the soil, became parts of particular plants and trees, dissolved in the oceans and then floated back up again into the air.

Some of my atoms will become parts of other people, particular people. Certainly, that's a kind of human connection, just as my atoms are connected to the stars. Backwards in time, into the far distant past… and forwards in time, into the far distant future, we connect. We connect.

I don't believe in any kind of cosmic meaning. Each of us has to find meaning for ourselves. Here's what I've come to: whatever this strange universe we find ourselves in, we're part of it. We're connected. That's meaning for me. And there's something else…

Galileo's Law for pendulums… Einstein's Law for gravity… although our single lives are flickers in the depths of time and space, the laws of nature we have found will last forever. And that's a type of immortality.

END ANNOUNCEMENTS: [56:12]

For background on the science presented in this program, and interviews with the people profiled, as well as a discussion guide, web-exclusive videos and much more, please visit: SearchingForMeaning.org

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SEARCH DEEPER

CONVERSATIONS

- Robert Desimone
- Rebecca Goldstein
- Erik Sorto
- Rai Weiss
- Nergis Mavalvala

LOCATIONS

- McGovern Institute
- Rancho Los Amigos
- Einstein Haus
- LIGO
- Sphinx Observatory

WEB SPECIALS

- Erik Sorto: Paying Back and Moving Ahead
- The SCIENCE & SURGERY Behind the Erik Sorto Story

ALAN'S RUMINATIONS

- Alan and Einstein's Ghost
- The Brain and Consciousness

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