

ADAM GAZZALEY INTERVIEW PART THREE

Hello again, Ars Technica listeners. This is the third and final installment of my conversation with UCSF neuroscientist Adam Gazzaley, and his extraordinary work in developing the medical potential of video games. If you haven't yet heard parts one or two, there are links on the page where this player is embedded, and I strongly suggest you go back and listen to them before this installment.

Finally, a quick note of -- orientation. I originally thought this podcast series would be a limited set of just eight episodes connected to my latest science fiction novel, which is also called *After On*, and which came out last summer. But the podcast acquired a life of its own, and I'm about to publish episode #38 in the ... series of eight.

As you're about to find out, these first eight episodes have a distinctive format, in that each of them ends with a conversation between me at Tom Merritt - who you might know from CNET, from TechTV, then later from Leo Laporte's network, and now from Tom's own videocast, Daily Tech News Show. In these closing conversations, Tom and I discuss the day's interview, and also a chunk of the book.

The segment you're about to hear will end with one of those conversations. And you may, of course, want to skip it. But you may not. Because although Tom and I mention the spoiler potential of our conversation, listening to it now, there actually aren't any *real* spoilers. Which could matter to the 1% of you who might actually want to read my novel.

Whereas if you have zero interest in the novel - Tom and I do continue discussing the themes of the interview with Adam. We also discuss the process of writing - and how science informs and influences science fiction. Tom is a prolific science fiction author himself. So if you're interested in storytelling in general, it's something of a backstage look at how those of who concoct these things go about it. I'll add that a lack of familiarity with the novel shouldn't really cause you to get lost in this conversation. So, you might just find it interesting.

And with that - back to my conversation with Adam Gazzaley.

TRANSITION MUSIC

Rob Reid:

So, I just want to close on something, it will segue into the second part of the podcast in which Tom, Ellie and I discuss part of the novel *After On*. The model of consciousness that's represented in *After On* sprang fairly directly from conversations that you and I had before I started writing it, and I'd like to focus on one thing, which I find fascinating in your theory of consciousness, and I did end up putting into the novel, so I find it doubly fascinating, I guess.

Rob Reid: And in the section of the book that Tom and I are going to discuss at the end of the podcast, a neuroscientist who just happens to be from UCSF as it turns out, but it's a woman, so it's not you, tells a character with a cataplectic disorder the following things about goals. And so, they're sitting in her apartment, she says, "I doubt you're even registering 1% of your sensory input. You're hearing the part of your field of view that I'm occupying plus the sound of my voice, but you're blotting out everything else, because your goal of conversing is shaping your sensory experience. It's drastically amplifying the tiny subset of signals connected to our words, and negating everything else. Goals are basically cognitive actors, you could almost say they make us conscious."

Rob Reid: I'd like to talk about the significance of goals in your own understanding of consciousness and human cognition broadly speaking, because I do find it kind of intriguing.

Adam Gazzaley: There are two ways that we interact with the world around us. One is what we call top down, it's how you perceive the world and attend to the world driven by your goals. You're paying attention to my voice now, because you choose to, not necessarily because it might even be the most salient thing around you, but you're choosing to. You made that decision, and that is a very human apt in many ways, is this top down. We are drenched deeply in top down experiences, especially in the modern world.

Adam Gazzaley: The other way we address-

Rob Reid: The top being the kind of imaginary person in the control tower.

Adam Gazzaley: Yeah, exactly.

Rob Reid: Who's saying, "This isn't the goal" [crosstalk 01:04:24] goal generating entity.

Adam Gazzaley: Of your identity, right.

Rob Reid: Yeah.

Adam Gazzaley: The other aspect of how we interact with the world is much more ancient, and also equally important in many ways, and that's called bottom up. That's how we attend to the world based on the environment itself, not our goals. So, if there's a flash of light, a loud sound, even your name, which has now been deeply programmed into your brain, even if your name is said quietly behind you, it will command your attention independent of your goals. We are constantly navigating the world through this interface of top down and bottom up. It's just how we live.

Adam Gazzaley: My theory of consciousness is sort of built around the idea that it is in this space between top down and bottom up that consciousness really emerges, that if you are only a receptacle to influences from the environment as other animals

are. Now, there are animals that also have top down goals, too, and have at least some version of what we think of this consciousness, but if you go to single celled animals at an extreme, or animals that are really almost completely reflexively responsive to the environment, then I would say that they don't have consciousness at that level.

Adam Gazzaley: Likewise, we don't really have examples of this, but if you're completely top down, and have no sensory input, but again you cannot emerge consciousness because you don't have an experience of the world around you, which only comes through sensory input. So, that's where I find that concept of consciousness emerging, at least in my own understanding of this interface of top down and bottom up.

Rob Reid: And that perspective on consciousness may or may not be found deeper in the novel than the part that Tom and I are going to discuss today, and that people who are both listening to the podcast and reading the novel have presumably read up to. There won't be any spoilers here, but that is a very interesting perspective, and one that subset of listeners who are actually reading might find interesting to attune to as they get deeper into the book.

Rob Reid: One final thing, I know you read a fair amount of science fiction. Are there any works of science fiction, whether written, or filmed or TV, or some other form that was particularly inspiring to you as a kid in your choice to go into the sciences, and or are there any works of science fiction that you think do a particularly good job of exploring the field that you are scientifically active in?

Adam Gazzaley: Well, I would say I'm probably not alone in this, being really inspired by Isaac Asimov. His foundation series was mind blowing to me, and there's actually EG in there.

Rob Reid: Is there? [inaudible 01:07:13]

Adam Gazzaley: Yeah, yeah.

Rob Reid: I got to go back and read it.

Adam Gazzaley: In the second foundation, and it's really interesting actually to read it again years later. So much of science fiction has been inspired by Asimov's work in the 50s, and so that was a big part of my sort of inspiration and science undoubtedly.

Adam Gazzaley: Now, I try to read science fiction every single day. The news has sort of preoccupied me a little bit, and pulled me away from science fiction, which is sort of pissing me off.

Rob Reid: It also pisses off the science fiction writers of America, I'll tell you.

Adam Gazzaley: I still try to not read the news as much as read science fiction. And the ready why is because I like challenging my imagination and thinking about the future, and then bringing aspects of that, that I think are tenable immediately into our lab and into our research practice.

Rob Reid: Superb. Well, thank you, Adam, for being so generous with your time, and for inviting us to your lab.

Adam Gazzaley: Thanks for coming by, it's been a fun time discussing this with you.

Rob Reid: So, that was my fabulous interview with Adam at UCSF, and Tom and I are now back together to talk about what we just heard.

Tom Merritt: Yeah, and you know, I noticed that Adam features prominently in your acknowledgements page. How was he engaged in the creation of the book?

Rob Reid: I actually probably spent almost 100 hours interviewing people as I was researching the book to get smart about specific areas, obviously in this case, consciousness and neurosciences. And also, to get smart about just lots and lots of fields as I was really deciding what to write about. Everybody I talked to was incredibly generous with their time, but Adam and I spent many, many hours together, and he had a huge influence on the model of consciousness that I decided I wanted to represent in the book, and also gave me the confidence that I understood what's happening in neuroscience well enough to, although what I wrote is fiction, it is at least plausible based on what we know already.

Rob Reid: So, he was a great asset, and frankly, one of the reasons why I'm doing these podcasts is I was unable in the novel to go into as much depth as I'd like to into the really exciting work that Adam and some other folks that we'll be interviewing in future episodes are doing. Much as I'd love to put a 20 page digression into the book about consciousness, that's pretty lousy storytelling, so we get to do that here on the podcast.

Tom Merritt: Yes, I like this better than footnotes.

Rob Reid: Yes.

Tom Merritt: Anything like that. Not that there's anything wrong with footnotes when used in the proper venue.

Rob Reid: Not that there's anything wrong with that. Yes, exactly.

Tom Merritt: But we are about to get spoiler-y, so if you haven't read the appropriate pages 51 through 109, and you don't want to be spoiled, you can move away now. But I want to start by talking about moats, they play prominently in this section. Where did you come up with moats?

Rob Reid: They are totally made up, and I consider them to be more fiction than science fiction. I know that's kind of a hairsplitting definition, but in the last episode, I said I believe I commit science fiction three times in this book. This is fiction, this is just sort of making something up about the world that we inhabit, rather than something being done with technology that we cannot do today, which is more science fiction.

Tom Merritt: You weren't looking at a study of moats.

Rob Reid: No.

Tom Merritt: And then, extrapolated.

Rob Reid: I'm making something up in the way that somebody who's creating a work of fiction that is not science fiction would make it up. The reason I came up with this model is I've always been intrigued by the fact that the infinite variety of life on this planet is written in base four. There are four types of base pairs in DNA, that's it in every living thing with some very exotic exceptions that prove the rule. Every living thing is based on that very essentially digital language. I mean, it's not precisely digital, it's not base two, it's base four. And that's true of a lot of elements of the universe.

Rob Reid: There are four fundamental forces. Strong nuclear force, weak nuclear force, gravity and the other one. Electromagnetic.

Tom Merritt: Up, down, strange charm.

Rob Reid: No, no, now you're getting into quirks, and there's six types of quirks. So, I've always been fascinated by these extravagant diversities that arise from very, very small numbers of combinations, and as Ellie said in the book, also all the colors on your screen are RGB, or perhaps CMYK if you're using print.

Rob Reid: So, I got kind of intrigued by the notion of emotions, which are arguably in some ways, so long as we're the only intelligent species that we know of, among the most powerful forces in the universe. They're very powerful things that emotions have the power to cause us to do things that then shape the macro environment in very, very significant ways, and I like the idea of them being digital. And it also played into a broader narrative that I'm not going to go into too much depth, because it would involve some spoilers, about how they hook into consciousness, how that consciousness touches on Mitchel's cataplectic disorder, Falkenberg's disease and other things. They're an elegant way to stitch together lots and lots of elements of the story.

Tom Merritt: Now, the way you wrote the moats is so fitting to human experience that I personally would not be shocked if someday there is some study that comes up with something that is similar to that. I mean, but you just pulled this all out of your own feelings, for lack of a better word.

Rob Reid: Yes. This was an entirely made up field of science, and by God, if it does turn out to be true, do I ever deserve a Nobel?

Tom Merritt: The read effect.

Rob Reid: Exactly.

Tom Merritt: Okay, so, you mentioned Falkenberg's disease. Where did you come up with Falkenberg's disease, and do you know anyone who has it?

Rob Reid: Thank God, no, because it would be a horrifying disease. I commit science fiction three times. Here, I commit horror story. Falkenberg's disease is an invented disease. It's basically a combination of two things. It's a derivative of narcolepsy combined with what some call Lou Gehrig's disease, or ALS. The way that people die of Falkenberg's disease is quite a kin to how they die of ALC, only because I was in horror writer mode. I made it worse with this sort of burning sensations that are described as being the final step down this horrifying journey.

Rob Reid: And I've unfortunately known a number of people who have had neurological diseases over the years. Some who survived them, and died of other things. Some people who died of them, and some people who are still fighting them. But there is something that is so terrifying and poignant about them, and I also thought there was something, I find there is something very poignant about cataplectic disorders. We're probably most familiar with people suddenly falling asleep, but there are other ones, as well. They do occur with surges in emotional states. Some cataplectic disorders get caused by laughter. So, it's not just narcolepsy, and sometimes people who are narcoleptic fall asleep when they laugh, and the notion that you could be sort of like [inaudible 01:16:52] to your emotions in a very physical way, rather than simply the perceptive way, and the opinion shaping way, and the action shaping way, which is frankly plenty for the rest of us, also struck me as poignant.

Tom Merritt: And the elements of synesthesia to this, as well.

Rob Reid: Yeah.

Tom Merritt: One input is transmuted into something else, but again, horror writing style. You transmuted it into something awful.

Rob Reid: Yeah, why not.

Tom Merritt: So, you've committed fiction, you've committed horror. Let's talk about one of the instances of you committing science fiction, the imaging technology described in your book. It goes well beyond the capabilities of MRI and EEG.

Rob Reid: As Adam clearly stated in our interview.

Tom Merritt: Yeah.

Rob Reid: And I did actually bring that out deliberately.

Tom Merritt: Now, you said you committed science fiction just three times.

Rob Reid: This is number two.

Tom Merritt: This would be the number two, okay.

Rob Reid: This is number two. Yeah. And I first got really intrigued by MRI. There was an utterly fascinating TED Talk in 2013 in which a woman who at the time was working for Google showed how MRIs could basically intuit, in some cases, with chilling precision what the subject was looking at, at that moment, and at times what the subject was thinking of. And basically what happened was, a person would be looking at a series of images, and she put up on one screen the series of images that the person was actually seeing, and on another screen the series of images the system inferred the person was seeing based on brain activity coming out of a highly sensitive fMRI.

Rob Reid: And it was chilling, because this was mind reading. Literally, mind reading. And knowing that systems improve over time, at that point in 2013, I was like, oh my God, what will they be able to do in six or seven years. Now, as we both all found out from the conversation with Adam is that I found before I started writing, there really is no Moore's Law curve for this stuff. MRI machines are going to continue to improve, but more at an arithmetic than an exponential level, and there's not going to be a radical breakthrough on that or on the EEG front.

Rob Reid: But the thing that I felt could be an out of the box thing that would chatter them both is what if you come up with a way to bring the two together, which is what happened in Ellie's lab. Little bit of science fiction. So, as with the MRI, you can see very slow things, but tiny things. Why is the MRI so slow? Well, the reason is, and I find this kind of interesting, is it's all about blood flow. So, the blood is lighting up this region of the brain, it's lighting up this region of the body as it dashes there because there's activity, and the activity calls for oxygen and glucose and the other fuels that the blood brings with it.

Rob Reid: But the resolution that you can get is therefore by definition limited by your heartbeat. The heart beats, and more blood shows up, and then more blood might be like, oh my God, I've got to get to the hippocampus right now, but it

can't do its next dash toward the hippocampus until the next beating of the heart. And so, that's why MRIs are so slow, they're kind of measuring [crosstalk 01:19:57].

Tom Merritt: The pace of a heartbeat.

Rob Reid: The pace of ... that is the cadence that they move at. And then, obviously, EEG, because it is electrical fields. You can get very, very fast results, but you are getting occluded by the skull.

Rob Reid: So, my little bit of science fiction was combing the strengths of both systems. It's not inconceivable that this'll happen someday, and if it does, it'll be the kind of breakthrough that'll allow for sudden and unexpected discovery. So, what this did from a storytelling standpoint is it gave me a place to hide my moats where Ellie could discover them.

Tom Merritt: Well, and it is perfectly reasonable to think there is something hiding in that gap, in the lag if you will.

Rob Reid: There is stuff we simply cannot see, because it is both fast and small. There is a vast world of things going on in the brain that we cannot see.

Tom Merritt: We just inferred that memories are stored in an 11th dimensional network, recently.

Rob Reid: For instance, yeah.

Tom Merritt: And that's something that we did with the current technology. Imagine if you could see more of what's going on, and make more connections.

Rob Reid: And we'll get there, and until we can, we'll just ask Ellie.

Tom Merritt: Yeah. Exactly. Now, listen, at this point, we've seen Amazon reviews, we've met Mitchel and Kooba in the present and the past. We've read some Net Girl. We've been to Tony Jebson's .com bust part at Momo's, which by the way, side note, part of my love of your story early on was that I have been to the Bourbon and Branch, and I've been to Momo's. In the times in which they appear, I went to Momo's at that .com era boom.

Tom Merritt: But did anyone ever try to order you to stop having so many of these elements?

Rob Reid: You should've seen the first draft. But actually, I'd say that most of the people connected to the book as I was writing it. My editor, my wife, my agent, and others, as well, thought this crazy diversity of modes and voices make the book special and unusual. But it was still a constant balancing act between too much, and hopefully just the right amount. I mean, if you look at the first draft of this book, it's now about 30% shorter. And in the course of rewriting, I fired a major

character, who is just not in this book because he got fired, and that was a doozy after a first ... I mean, there was a sixth major character, he's just gone now. That's a doozy of a change to make.

Rob Reid: I ended up having all this flashback stuff going on with the past, that wasn't in there. I took on a narrator. So, pretty big things happened, and I culled a couple hundred pages from the book. Now, needless to say, my editor at Random House, Tricia Narwani, was critical to all of this. And I describe our working relationship in some detail in my acknowledgements page. And I also had a couple dozen people read work in process version of the book, and inhaled input from all kinds of people, and I think you need to have a very special relationship with criticism and with feedback if you're going to be a successful writer, because you have to be very good and unemotional about taking it. But you also have to have a lot of backbone about ignoring a lot of it, because if you end up implementing everything you have, if you're so open to feedback, you're going to end up with a book that gets written by committee.

Tom Merritt: One of the biggest things that I learned in journalism school from the editor of Journalism 350, The Introductory Course, was when he told me I'm going to rip apart every story you give me. You don't have to take any of my edits, but you better have a really good reason why. And that's exactly what you're talking about, is knowing when to say, you know what, I know you're all saying that, but I have a really good reason why I can't do what you're saying.

Tom Merritt: Now, another way in which people can get even more out of this story is listening to the audio book, because another thing that I think you've done very well is an ensemble cast.

Rob Reid: Yes.

Tom Merritt: And I don't say that just because I read the New York Times' parts.

Rob Reid: You are one of the ensemble.

Tom Merritt: But because you have much better people than me, people that I enjoy and admire, doing perfect parts. And now, we mentioned Felice O'day reading the Net Girl parts. Do you have someone special reading the Amazon reviews, as well?

Rob Reid: Oh, yeah. So, here we have John Hodgman. Now, John and I go back a ways. He actually read the entirety of my last novel, Year Zero, and he read it magnificently, and so I recommend John Hodgman's audio book of Year Zero to anybody. When I got to these reviews, they were playing in my brain in John Hodgman's voice. Just sort of the dry-wit, the Bostonian dimension. John is from the Boston area. The particular category of humor, the use of vocabulary, everything else.

Rob Reid: Later on, I'll talk about it in a later episode, how I actually wrote all these before I met Hodgman, which is an interesting statement, because I've known Hodgman for almost 10 years, and I think I mentioned earlier, I just started writing his book a couple years ago. So, there's a mystery we will get back to.

Rob Reid: But after I met Hodgman, I forever thought of these reviews as being in his voice, and I was lucky enough to be in the recording studio when he recorded these reviews, and it was like the culmination of imagining something being just the way it should be, and then suddenly hearing it exactly as it was meant to be. Why don't we listen to Mr. Hodgman read a Higginsworth review, or two right now.

John Hodgman: Storm 3000 Tsunami Force Five. Five stars. Axes of evil beware, Young Charles is armed. November 22nd, 2001. Your reviewer, Charles Henry Higginsworth III from Boston, Massachusetts.

John Hodgman: Our twins turn four this summer, and a grown woman selected this hydrant class spray toy for her daughter to gift to my son. I like to believe Amanda's mother knows nothing about our home décor, nor of my son's volcanic side, otherwise I might suspect that my first wife coxed her into sabotaging our once lavish interior's few remaining valuables, which, well not water salable, we're anything but water resistant.

John Hodgman: The Storm 3000 Tsunami Force Five spews its destructive payload about 20 feet, cleverly illuminating it with a photon beam. Translation, a ray of light. Allowing the proud homeowner one final glimpse of his cherished antiques in mint condition. And your little brown shirt needn't limit his ordinance to water. Young Charles's field tests showed that Gatorade, soy sauce and Diet Dr. Pepper all erupt from this ingenious device's muzzle at full velocity. Hybrid payloads of Perrier mixed with obsession fragrance discharge more diffusely, enabling efficiency minded vandals to saturate entire racks of dresses with a single round.

John Hodgman: Indeed, just such a volley provoked the instant and unexpected conversion of Charles's mother into a gun control zealot. She had previously been more co-conspirator than chaperone in the proceedings, on account of her Latina [inaudible 01:26:50] and youthful exuberance. At 26, she's marginally closing to our son's age than to mine, and it does show in instances like this. Happily, little Amanda's own birthday was by then on the horizon, and we repaid her mother's kindness with a First Act Discovery drum set, which is also available in this store.

John Hodgman: First Act Discovery drum set. Five stars. [inaudible 01:27:18] [Millitude 01:27:19]. December 1st, 2001. Your reviewer, Charles Henry Higginsworth III, from Boston, Massachusetts.

John Hodgman: Our four year old son recently received a Storm 3000 Tsunami Force Five water howitzer as a birthday present. It was ostensibly a gift from his little friend

Amanda, but her mother was clearly behind this wicked act, which soon resulted in the complete saturation of our living quarters. Happily, Amanda's own birthday was near, and when the great day arrived, we retaliated by sending Young Charles to a party with this as his offering.

John Hodgman: I am happy to report that these drums are louder than bombs and more addictive than Pokemon. Three months have passed, and Amanda still drums daily, according to intelligence gathered by Young Charles during play dates. When her interest briefly waned, I urged Charles to refocus her on the crash symbol during his next visit. This rekindled her passion for music making, as did some old Keith Moon videos I later screened for the play group.

John Hodgman: Amanda now adroitly mimics Keith's old stunt of knocking the drum kit to pieces at the end of each set. A true case of life imitating art.

Tom Merritt: Achievement unlocked.

Rob Reid: Achievement unlocked. So, that was Hodgman doing a magnificent job of reading these in the ensemble audio book, which is I believe, I think it's 22 hours long.

Tom Merritt: Yeah.

Rob Reid: Yeah. It's a long book.

Tom Merritt: Now, that is a goal achieved, and both Ellie and the book, and Adam in your interview talked about goals being cognitive actors.

Rob Reid: Yes.

Tom Merritt: Now, since you quoted Ellie to Adam in your interview, I assumed this is an important part of the storyline.

Rob Reid: It is, and it's a very interesting theory in neuroscience that could just be right. Now, Adam mentioned this idea of goals as cognitive actors over dinner that we had before I even started writing the book, and I found it fascinating, and I ran with it.

Rob Reid: Now, I should point out, this isn't Adam's main field of research. It's more a part of a worldview that he's developed over the decades that he spent in the field. But it intrigued me, and it still does, because goals absolutely do shape what we're allowing in. We're getting this gale of input from our bodies, from the bottom up as Adam would say. Every photon, every sound wave, every fleck of skin is constantly reporting, and it's that which I want to do in this moment, my goal, that's hitting the mute button on almost all of this, and thereby shaping this into a parsable experience.

Rob Reid: So, that goal is a cognitive actor, yet you need that bottom up input, as well. It's vital. You need that collision, that dialogue between goal and physical input. And what this could mean, is a consciousness needs something like a physical body in order to arise. And Adam himself said, I'll quote him from the interview we just did, "If you're completely top down, and have no sensory input, again, you cannot emerge consciousness, because you don't have an experience of the world around you, which only comes through sensory input."

Rob Reid: Now, interestingly in my research, I came across three or four other neuroscientists who very speculatively said something quite similar to this. All of them independently, and all for very different reasons, and so I became very enamored with this notion of consciousness arising via a physical body interacting with that seat of volition and goals. And so, this is just not a spoiler, it's just something to be attuned to, I ended up thinking that this would be a very interesting way for consciousness to arise, for even if something was digital and didn't have a physical body, for it to have some kinds of physical inputs that could create that top down bottom up collision, which may just result in consciousness.

Tom Merritt: So, if I may, if goals are cognitive actors, and your goal was to get John Hodgman, he is your cognitive actor.

Rob Reid: In a sense.

Tom Merritt: In a sense.

Rob Reid: He is. Yes. Many people are our cognitive actors.

Tom Merritt: I think that-

Rob Reid: John will be flattered to know that.

Tom Merritt: If you haven't realized it, that means we're at the end of this episode.

Rob Reid: We are indeed.

Tom Merritt: Next episode, episode three, we will cover pages 110 through 180, and our guest will be talking about digital privacy and government intrusion.

Rob Reid: Yeah, and it's a really fantastic interview, and I'm excited about our guest. It's Cindy Cone, who runs the Electronic Frontier Foundation, EFF, which is at the forefront of all of these issues of government intrusion and privacy in the digital age, and we talk about all of this stuff.

Tom Merritt: So, if you want to get that, go find it right here wherever you found this episode, and if you want to find out more about After On, if you want to catch up, if you want to keep reading, go to After-On.com.

Rob Reid: Thank you so much for listening.

END MAIN BODY OF PART THREE

TRANSITION MUSIC

So Ars Technica listeners - here we conclude the third and final installment of my interview with Adam Gazzaley. I do hope you enjoyed it. In case you're interested, current episode of my show is an interview with Great Britain's Astronomer Royal, Martin Rees. We talk about the most eerie and violent phenomena in the known universe. Specifically, gamma ray bursts in the violent department; and fast radio bursts in the eerie department. We also spend a great deal of time discussing the existential risks society might face in the 21st century, which is also the topic of the article series that I'm posting to Medium of this month - which you can find at [Medium.com/@RobReid](https://medium.com/@RobReid).

You can find the Martin Rees episode by visiting my site, at after-on.com. Or, just type the words after- n into your favorite podcast player, and scroll through the episodes. You'll find lots of stuff about life sciences - above all, genomics and synthetic biology. Conversations about robotics, privacy and government hacking, cryptocurrency, astrophysics, drones, and a whole lot more.

Or, you could just join me next week, here on Ars.

OUTRO MUSIC