[SLICE OF MIT THEME MUSIC]

ANNOUNCER: You're listening to the *Slice of MIT Podcast,* a production of the MIT Alumni Association.

[PHONE RINGING]

DAVID SCHWARTZ: David Schwartz.

JOE MCGONEGAL: Hi, David. It's Joe McGonegal at MIT.

SCHWARTZ: Hi, Joe.

MCGONEGAL: Thanks so much for doing this. I've been really looking forward to chatting with you. It's the *MIT Alumni Books Podcast.* Read a little introduction, and then jump into the first question.

SCHWARTZ: Very good.

MCGONEGAL: David N Schwartz, PhD class of 1980, is the author of *The Last Man Who Knew Everything,* published by Basic Books in December 2017. It's Schwartz's third book. His first two being *Ballistic Missile Defense* and *NATO's Nuclear Dilemmas.* David, tell me why a biography of Fermi now?

SCHWARTZ: You know, he was an extremely significant scientist, one of the most significant of the 20th century. He's revered by physicists, but he's almost forgotten among the general public. I was amazed to find that the last English language biography of him was done in 1970. I decided I wanted to set out to write a book that would change that, establish him where I thought he deserved to be.

MCGONEGAL: You say his fame has diminished as his legacy has grown. Explain that.

SCHWARTZ: Well, his legacy has grown enormously. Practically everywhere he turned, he opened up new fields of physics. A quick example, the weak interactions really are a result of his work on beta decay. And much of what goes on at the Large Hadron Collider today is based on weak interactions and neutrino physics. And the Higgs boson was, of course, an outgrowth of a series related to weak interaction. So his legacy is enormous.

And physicists know him, yet his fame has really diminished. He wasn't a publicity hound. He was sort of diffident when it came to being in the public eye. He was much more comfortable when surrounded by colleagues or students. And so after the war, he had a minor bit of celebrity with the publication of the *Smyth Report,* which detailed his role in the Manhattan Project. But he didn't really exploit that celebrity, quite deliberately, I think. And so I thought we really needed to remind ourselves about this great scientist who has been forgotten.

MCGONEGAL: And at least the first half of the book or so, is really an intellectual history of how this brain, Fermi's brain, formed. Fermi is born in Rome. He essentially has an undergraduate education from a mentor who tutors him before going to university. And we learn about the strengths and limitations of Italian pre-war university education and limits of their libraries for him as he devoured everything.

SCHWARTZ: He was someone who had first of all, an extraordinary foundation in basic physics that he got, as you said, through this mentor that he met when he was 13. So by the time he was 18, he had mastered all of classical physics. And he had done it rigorously and grinded it out. He just read every book he could find, including a 4,000 page treatise of all of classical physics. So when he arrived at university, he knew classical physics completely and comprehensively.

And then he went and taught himself relativity and quantum theory to the extent that it was understood in those days in 1918, 1919, 1920. He was self-taught, had an enormous ability to integrate all this material. He had a tenacious curiosity about things. And he had this ability, which he developed during this period, of stripping down problems to the simplest form, and being able to solve them using a tool kit that he had developed during this period. Watching him become Fermi, as it were, was a fascinating thing for me as a writer.

MCGONEGAL: Tell us the story of Fermi's entrance exam to university in Pisa, where he was suspected of cheating.

SCHWARTZ: Yes. Well, I'm not sure he was suspected of cheating as explicitly, but they certainly wanted to see who had written this exam. It was an exam that discussed the physics of a vibrating rod, and analyzed it in terms of fairly advanced physics using eigenvectors of the Fourier transforms. It was the kind of treatment that you would expect from a graduate student, not from an undergrad who's entering university.

So the examiner called him in-- it's not clear whether he called him in to grill him and make sure that he had actually done that, or whether it was to congratulate him, and maybe it was

both-- but in any case, the examiner ended up saying to him that he was convinced that Fermi would become a very, very important scientist. It's one of the legendary exams ever submitted to the Scuola Normale Superiore, Italy's most prestigious school.

MCGONEGAL: Today we have the archive in the physics world of planting your flag on intellectual property online before you published a preprint website. Talk about the frustrations Fermi and others had in holding their turf 100 years ago.

SCHWARTZ: That is a fascinating subject. Fermi had some problems with this early on. In the book, I describe how when he published his so-called statistics, which were a way of integrating Pauli's exclusion principle into statistical mechanics, about three or four months later Dirac published a very similar piece. And Fermi was quite upset because Dirac made no mention of Fermi's article.

In those days, preprints weren't really very commonly used. I think a few years later when Fermi decided to start bombarding elements with neutrons to see if he could irradiate them, he began to use preprint as a way of establishing priority, sent those preprints out by fast mail to all the major research centers in Europe and in the United States. So very quickly he began to use the preprint process to establish priority of discovery. That was very important to him. He was a very competitive guy. And during this particular period in fact, he was most concerned that the Curies or Rutherford would beat him to the punch on some of these things. He felt he was in hot competition, and used the preprints to further his own claims.

MCGONEGAL: Often with the word tentative in the title.

SCHWARTZ: Yes. He used the word tentative with the theory of beta decay because he was a little concerned that there was no proof to his theory at all, although it made perfect sense. In fact, the legend is that particular paper was rejected by *Nature* magazine for being too speculative. But as I say, I'm not sure that that legend is actually true.

MCGONEGAL: You focus on some of his regrets, his 1934, quote unquote, "discovery of transuranic elements," but he had really discovered fission, is that correct?

SCHWARTZ: Yes, that is, but he didn't know it. He didn't know it at the time. Later in his life, he referred to himself as the man who missed fission. He had been irradiating uranium with neutrons, and the byproducts were very difficult to analyze. It took the greatest radiochemist in the world four years to understand what Fermi was looking at. The radiochemist that he had working with

him was perfectly competent, but didn't understand that there were much smaller, much lighter elements in the byproducts that could only have come from the fission of uranium.

They thought in fact, that they were looking at heavier elements. And Fermi got some publicity for having discovered supposedly, heavier elements than uranium. Turned out that that was wrong. And he always regretted having missed it. But you know, in retrospect we're probably quite fortunate that he did, because if he had understood what he was doing in 1934-- that he had actually split the uranium atom-- it might well be that the fascists would have been the first to get a nuclear weapon, and that would have been a disaster.

MCGONEGAL: And would have been the Rome project, not the Manhattan Project.

SCHWARTZ: Yes, and it would have been a catastrophe. So we're all, I think, fairly lucky that Fermi didn't realize what he was doing at the time.

MCGONEGAL: I wonder if you can just take us to the night of the Trinity test in Los Alamos. And it exemplifies your frustrations really with finding a lot about Fermi's emotions and his feelings. He didn't write, he didn't keep a diary, he didn't write much. But what did you discover about his emotions that day and in the aftermath?

SCHWARTZ: It's very interesting. Before the test, the day before the test, he seemed to be in a jovial mood and was making bets with physicists about whether the atmosphere would actually ignite during the Trinity test, which there were some Army police who overheard this and got panic stricken and went to the head of the tests with their worries. And Bainbridge, who was the head of the test, called Fermi in and scolded him for having unnecessarily scared people. So he was sort of in a jovial mood beforehand.

And then the tests occurred, and he did the famous paper strips experiment, where he waited for the blast wave to hit him and allowed some paper strips to scatter in the blast wave, and measured how far they went, and was able to do a back-of-the-envelope calculation as to how high the yield of the test was. And it was reasonably accurate. It was accurate certainly within an order of magnitude, and he was quite happy with that. I think afterward-- that day he began to get more and more-- I guess the word would be frenetic and a little bit off-kilter.

And in fact, he loved to drive, and he drove back to Los Alamos with Sam Allison-- who was a close colleague of his-- and he asked Allison to drive because he felt that he couldn't concentrate on the road, he was too distracted. Although he did very interestingly-- they had a

flat on their way back to Los Alamos-- and Allison went ahead to find a gas station, and Fermi stayed behind with the flat tire, and drove up about 15 minutes later, explained to Allison that a physicist had passed with a canister of argon gas and they had used argon gas to fill up the tire.

So even at that point, he was not completely without a sense of humor. But I think it did upset him. He didn't talk about it ever. But if you read the memoir of his wife, you definitely get the sense that he understood the enormity and the magnitude of what he had just witnessed.

MCGONEGAL: Your cover photo on this book, it's a marvelous design. It's a telling photo. You remind us again and again through the book that Fermi liked to run ahead of the pack.

SCHWARTZ: Yes. He was very competitive. And he was a real outdoorsman. It's a lovely photo. It was taken by Leona Libby-- one of Fermi's close colleagues during the Chicago years, they just adored each other-- and it's clear that she stood in front of them as they were running and she snapped the photo. And we were very lucky to get one of Leona's sons to give us permission to use that photo, because I think that it captures a lot of Fermi's personality.

MCGONEGAL: You do wonder aloud though, whether or not at some point of his rushing back and forth during experiments holding the-- what was it, the tubes to his chest-- and then he dies of stomach cancer at age 53.

SCHWARTZ: It's not clear that it was caused by radioactivity, but it's possible certainly. He is the only one of the Rome group who died in these circumstances. But as I say, he was also front and center on these experiments, and probably shouldered the lion's share of the actual physical work. Now of course, people like Amaldi, and Rossetti, and others ran up and down the hall too and were exposed, but it was really, I think, it was Fermi who bore the brunt of it. But he wanted to be out in front. He wanted to be the leader.

MCGONEGAL: In terms of his adopted country, what did you learn about did he have a patriotic bone for the United States in his body?

SCHWARTZ: Oh, yes. I think he was a real patriot. He came to love the United States very early on. His first trip to the United States was 1930, and I believe that from that point on, he wanted to move to the United States. He loved the openness of the United States. He loved the relative lack of hierarchy. He also noticed that there was a lot more money in physics in the United States than there was in Italy. The fact that they welcomed him in to the most secret project that the

US military had going on at the time, he really appreciated.

And in turn, he was incredibly loyal to his country. I mean to the point where he just adopted all sorts of Americanisms. He wanted to be called Hank, because he knew that Enrico was the Italian equivalent of Henry. And he wanted to know what people in the United States are called if their name is Henry. And he heard that would be Hank, so he suggested that maybe people should call him Hank. Well of course, no one called him Hank. But that's the way he viewed the United States, he wanted to be as American as he could.

MCGONEGAL: It's the MIT Alumni Association, we have to ask you about two other alumni you chronicle, Vannevar Bush of course, 1916 PhD from MIT, and Richard Feynman--

SCHWARTZ: Yes.

MCGONEGAL: -- 1939 graduate. Who had more of an impact on this story?

SCHWARTZ: Oh, well Vannevar Bush is probably one of the most significant people in the entire Manhattan Project. He was a good scientist, but probably one of the best administrators that FDR had. He had a gift for organizational structure, and knew how to push an organization to do exactly what it needed to do on time and under budget. He was gifted that way. And he had the complete confidence of the president. He's a central figure in the Manhattan Project.

Feynman is not a central figure in the Manhattan Project as such. He was in charge of some of the calculations for critical mass, and he directed a bevy of computers. Now computers, in those days, were women who operated calculating machines, and he directed them in all the calculations acquired for establishing what the critical mass of uranium and plutonium would be. And everyone understood that Feynman was a brilliant guy.

And Fermi and Feynman got along very, very well. I'm not sure that Fermi and Bush really met each other very often. But Fermi and Feynman knew each other very well at the Manhattan Project, and remained very close after the war, would discuss all sorts of things related particularly to the experiments that Fermi was running on pion proton collisions in the nucleus.

MCGONEGAL: You talk about computers being human back in the 1930s of course, the title of the book, *The Last Man Who Knew Everything,* you do bemoan the fact that it's impossible for anybody to know theoretical physics and experimental physics as intimately as Enrico Fermi did in the early 1900s in 2017 due to computing, right? And just the massive computing power and the mass amount of understanding required to understand the computers.

SCHWARTZ: Well, I think that's certainly one of the aspects. These computers are enormously powerful, and the data that they crunch is beyond anyone's comprehension, beyond anyone's comprehension. So that's one aspect of it.

But I also think that experiments have gotten so big, that it's very difficult and so long-- I mean, these experiments take years and years to set up and run-- it's virtually impossible for any one of the 3,000 or 4,000 people on a particular experiment at CERN to have the time to devote to really understanding the theory deeply enough so that they can make a theoretical contribution. And for their part, theorists, it would take far too much time for a theorist to understand all the details of these tremendous experiments that go on at CERN. So I think the field of physics is now pretty much permanently divided between theorists and experimentalists.

MCGONEGAL: Customers who bought this book on Amazon also bought books-- the algorithm tells me-- by Karl Sigmund, Walter Isaacson, Paul Halpern, John Le Carré. Is the algorithm doing its job?

SCHWARTZ: I don't know why John le Carré is in there. To the extent that Fermi contributed after the war to the hydrogen bomb, and was involved at that level in the Cold War, I guess there is some relation. But I don't really see very much. Otherwise, the people that you've mentioned are all fine writers. And le Carré of course, is a brilliant writer as well. And it's wonderful to be lumped with all those people frankly.

But I know that Paul Halpern has just published this wonderful book about Wheeler and Feynman that I have on my nightstand ready to read. I've always wondered how the two of them got along because they were so different, Wheeler being a very formal, quiet man and Feynman being a bit of a gregarious, so wild man, sort of a clown when he wasn't doing brilliant physics. But apparently the two of them got along just famously. So I'm looking forward to that book.

MCGONEGAL: So you've answered my next question, what are you reading right now. But maybe after readers finish *The Last Man Who Knew Everything,* what's the next recommendation from you?

SCHWARTZ: Oh, the next recommendation from me is I'm a big fan of Leonard Susskind's books on physics called *The Theoretical Minimum.* There are three volumes now. One is on classical physics. One is on quantum theory. The new one that's just come out on special relativity and

field theory. And those are for someone who wants to do physics but doesn't want to go through the 20 or 30 textbooks required to have a graduate level understanding, these are perfect introductions.

And they're very clear. I'll give you an example, he goes through calculus in five pages. And it's a beautiful, beautiful exposition. And it's all a physicist needs to know about calculus in five pages. It's just beautiful. So I really recommend those books. Those are books that are just wonderful.

MCGONEGAL: Well, goodness to you for not including a single equation in this book either.

SCHWARTZ: I tried to keep the physics as accessible as possible to the lay person.

MCGONEGAL: David N Schwartz is the author of *The Last Man Who Knew Everything,* published by Basic Books in December 2017. David, thanks so much for joining me.

SCHWARTZ: It's been a pleasure. Thank you.

[SLICE OF MIT THEME MUSIC]