INTERVIEWER: Today is July 7, 2010. I am Karen Arenson. We are talking this afternoon with Donald R. Sadoway, the John F. Elliot professor of materials chemistry in the Department of Materials Science and Engineering. His research focuses on the use of energy and resources and on questions like how to store energy in automobiles and in stationary objects and how to extract metal ores and recycle metals.

He is also one of the most popular and most heralded teachers in the Institute, and has won repeated awards for his teaching including the MacVicar Faculty Fellowship. He teaches *3.091 Solid State Chemistry,* a course that can be used to fulfill the institute's chemistry requirement. More than half of the freshman class take 3.091, a course sometimes referred to as 309-fun. More students take this course then the chemistry department's own offerings.

Don, thanks for talking to us this afternoon. Students rhapsodize about that course. On the admissions blog, one student said it was the greatest class he had ever beheld, and that you fully deserved your five star ratings on YouTube. An alumni posting about you and your work carried the heading, Sadoway the Magnificent. And Bill Gates thanked MIT officials for putting your course online and told the Seattle newspaper that your classes were, "unbelievable." What's your magic?

SADOWAY: I think I begin from the perspective of trying to imagine myself as 17 or 18 years of age sitting in one of the seats in 10-250 hearing this material for the first time and proceed from there. I have recordings of the lectures, and when I prepare a lecture one of the first things I do is to view a recording of that lecture as it was last given. And I'll sit-- and it's probably been almost a year since the last time I thought about that material --and I'll watch that lecture, but trying to imagine myself as 18 and raised on MTV and Sesame Street and whatnot.

You know, when I was a youngster, there were times when my father would be watching television and there'd be some politician holding forth and all of a sudden I'd hear my father yelling at the TV as though the person could hear him. Well history has a way of repeating itself, so sometimes I'm watching the lecture and I start yelling at the TV, saying no, no, no, you can't go from that step to the next step. You left something out! And so I think part of that preparation is being able to look at what has gone forth in the past and try to tune it even further.

INTERVIEWER: Is it hard to put yourself into the shoes or the mind of a 17 year old? You probably weren't raised on MTV.

SADOWAY: I wasn't. I wasn't. I have three kids that were, but to the extent that I can imagine what it would be like to try to make the transition from home to college, and it's really a double jump because you're not going from high school to college. You're going from high school college, college to MIT. And as you know, MIT is a big jump. And so I try to imagine what these students are bringing with them in terms of preparation. Some of them have had several years of chemistry in high school, others took no chemistry. And so we've got a very wide range of abilities and preparation in the room.

The first month is difficult. It's hard to bring the first time learners along without boring to tears those that have seen the material in high school at sort of AP level. So it's almost like Sesame Street in there, that you've got the basic message, the most rudimentary lessons about electronic structure and bonding, and at the same time there's some deeper material. You know, when you're watching Sesame Street there's the double entendres that only the adults understand. But it can be done. You have to be able to teach to a heterogeneous mix when you're teaching a freshman class because of the wide range of abilities of the students that come in. They're all smart, but not everybody's had the same preparation.

INTERVIEWER: Did you ever have any teachers who taught like this?

SADOWAY: Well, no. No, I did not.

INTERVIEWER: And what got you thinking that this was worth doing? That it was something that you wanted to do, or needed to do?

SADOWAY: I think that back when I was still in high school, something about teaching and-- I've always valued education. I'm the first generation to complete college in my family, and education was always viewed as the key to social mobility, economic prosperity. And I always valued education. I had respect for my teachers and I saw it as something that maybe I'd like to do that, too. Spread wisdom to the extent that I could.

And so when I was in high school, I thought maybe if I go to college I could come back and teach high school in Oshawa, Ontario. And then when I got to college I said, I like this. Maybe if I go to grad school I could be a college professor. And so somewhere along the way I got the urge to teach. And when I got to MIT I just felt that, over time that there was a need in the big freshman classes.

When you look at the hierarchy of people around here, people dote on their grad students because the grad students are the partners in the research enterprise. Everybody wants well educated grad students because well educated grad students will perform, presumably, high quality research. When you look at the undergraduate students who are in the major, well if I'm in the materials science department, materials science majors are going to go out into the world with our brand so obviously we want to make sure that they are the best materials scientists at the Bachelor's level that people can hire.

But what about the freshman? They're unspecified. They haven't chosen a major. Who cares about them? Yet if you think about something like in an analogous situation, child rearing, the most important thing you can do to ensure a strong finish is to get them off to a good start. And yet what do we do in education? People play spin the bottle to figure out who's going to teach the big freshman classes. So I saw a need and I decided well let's get in there. And it's a challenge, but the ripple effect is huge. I guess it's been the right match of my urge and some institutional need.

INTERVIEWER: Were you always such a good teacher?

SADOWAY: I have no idea. I suspect things have gotten better over the years. I hope they haven't gotten worse over the years. I would say no. I would say that I've learned a lot over the years, partly from watching myself on video, but also by watching other people. I was fortunate that I was a recitation instructor in 3.091 when I first came to MIT and hired on to the faculty. And my predecessor Gus Witt was a fantastic mentor to me. Really I learned a lot from him. And it wasn't formal. I mean, he never sat me down and said, look this is what you need. It was just watching him.

He had this incredible ability to speak in 10-250 and I'd sit at the very back on occasion just to get a sense of auditorium and feel what the students must be feeling. And he spoke to people not as though he was holding forth in lecture mode. It was conversational. Gus was able to create the illusion of having a one to one conversation with 450 people. And I thought that's different. To an 18 year old who's used to being at the top of the totem pole, now to be at the bottom at MIT, quaking in their boots because their support network is gone, they're now miles from home and they're not sure they're going to make it here, to have somebody talk to them as though they're real people I think is an important piece of it.

INTERVIEWER: Do students who love a course necessarily learn more and retain more? Have you tried to measure that?

SADOWAY: I think that the answer is yes. Because these are bright students. In many instances I don't think I teach them anything, formally. I just tell them what's on the agenda. My number one role is to inspire them to learn. They can learn it themselves. When they come to MIT they're all good in math. Physics comes pretty natural, you know 801 is Newtonian mechanics and we all know the Newtonian world. Every one of us knows that if we throw a ball with a certain amount of force we anticipate what the outcome is going to be when that ball hits another ball of a similar mass. Biology is fascinating. It's the new science, and with the rapid advances over the past 25 years, people are fascinated to learn more about biology. And then there's chemistry. That's the subject everybody loves to hate. It's the one that was most poorly taught in high school.

So, that being the case, if my assumption is correct, my number one job in there is to get them to love the subject matter enough to crack the book. After that, they'll learn the material. So much of what I do in lecture is to engage them, to get them hooked on the subject matter so that-- my goal by the end of the semester is to have them reflect upon their first experiences at MIT and go home and say, you know what, I hated chemistry in high school but chemistry was my favorite class in my first semester at MIT.

INTERVIEWER: Do you think that the skills to be a creative teacher are the same as the skills to be a creative researcher? That there's something that is similar in both cases? Or are they really different kinds of creativity?

SADOWAY: I think they're different kinds in many respects. The business of being inventive in the laboratory or at the desk, I think that's quite different from being creative in a classroom setting. And here I'm talking about big classes. We could divide the teaching enterprise into small classes, say classes of 30 or fewer, to the auditorium where you've got-- once it's more than about 100 it doesn't matter if it's 500 or 1,000, it's just a sea. So how to put that subject matter across, it's not about finding the person who has the deepest understanding of electronic structure and bonding. There are people that know far more chemistry than I'll ever know that you wouldn't set loose in a room with a bunch of 18 year olds, even 18 year olds at MIT. Because the communication piece is the most important piece of good teaching. It's not the same, it to my mind, same part of the brain as being inventive in a laboratory setting.

INTERVIEWER: I was wondering if one needed to have a theatrical gene to pull off classes the way you do. But it sounds like you're describing it partly as a communications issue more than a performance issue. Or is it the combination of the two?

SADOWAY: It's a combination. It's a combination. I'll tell you why-- the performance is important in so far as you've got, as I've mentioned, you've got a large number of students and beyond about the seventh or eighth row, the lecture is just a tiny visual piece of the entire panorama. So all you've got, really, is your voice. Maybe you've got some broad gestures, but you've got to work at engaging to hold their attention. Because ultimately it's just a man with a piece of chalk. I can't go in there with a rock and roll band, and all sorts of video playing in the background-- that will trivialize the class. It'll make it into a parody of itself. Because it has to be serious. The students, above all else, have to respect the instructor as a teacher. And how to engage them using legitimate theatrical tools, if you will, I think that's important. But I've always maintained that content trumps form. If what you're teaching isn't valuable, or isn't seen to be valuable, they will turn off.

INTERVIEWER: One thing that seems to catch students' attention though is that you bring history, and art, and music into the classes. When and why did you start doing that?

SADOWAY: Well there are different answers to different parts of that question. The history was always part of 3.091. I recently asked that question. I can't remember, I was preparing a lecture about 3.091 at some point in the not too distant past, and so I went to my colleague, Tom Eagar who was an undergraduate here and eventually became my department head for a five year period in the last decade, so he was here at the time John Wulff launched 3.091.

It turns out Wulff was quite a raconteur. He was originally from Germany, and came to the United States. And Wulff knew a lot of these people. He knew Friedrich and Knepping. So he could talk about X-rays and the Braggs and all of this stuff. He knew Heisenberg. And being a raconteur he wove these stories into the fabric of the class. And then there were a number of people that taught, and then Gus Witt took over. And Gus was also European. Gus was from Austria. And you would have thought someone from Austria would have been very stiff and formal, and yet he was warm and he was charming. And he had this delightful Austrian accent and it was 3.091, Niels Bohr , and so on and so forth. He also talked about going to a camp when he was a boy, and Schrodinger who was also Austrian, was at this camp and so on.

So it became natural to tell these stories. And I think for me that was an easy way to engage the students instead of a litany of facts. And then this equation, begat this equation, which begat this equation-- so what did people think about the atom? What was the state of affairs in the late 19th century? So there's J.J. Thompson , and then along comes some new data, and then Ernest Rutherford , and then Neils Bohr comes from Copenhagen to study with J.J. Thompson , and then with Rutherford and then their grad students go on to here and there-- pretty soon it becomes a narrative.

It's almost like it's a 14 week soap opera and you come back for the next episode. So that was natural, and I've expanded upon it because I realize that a lot of these students don't understand the place and the time. Why is it that there were all of these Nobel prizes coming out of the Cavendish lab in the UK? And then quantum mechanics comes from Central Europe? And then the Nazis come to power and you have Jews leaving Europe, and people who are disgusted with the treatment of Jews leaving Europe. And then you see the ascendancy of American science. It's a powerful story. And why not tell it to freshman? And they get it. It's terrific.

Now the music is something different. The music was when I was first invited to take over 3.091, Gus wanted to rotate out, and so we reversed roles. So in the fall of '95, he took recitations and I became the lecturer in charge. So I was thinking as I was preparing lectures that on the day that I teach hydrogen bonding I would maybe play Handel's Water Music. So I was thinking about that and then it occurred to me, well why only on that day would I play music?

And so on the opening day of the lectures in the fall of 1995 as the students were coming into the class, I had, I think it was a Bach Brandenburg concerto, I think it was number one. And it was playing. I thought it was very sort of-- you know, it was Baroque, and I thought it would sort of be Cambridge-y. And then I think there was something by Sheryl Crow at the end because I'd talked about cars and there was a Sheryl Crow song that's talking about people in a bar on a Tuesday at noon, and the good people of the world washing their cars and so forth. And so then it became a challenge for me to make the match between the subject matter and the music.

And then from there came film. When I taught polymers, introduced the clip from the Graduate. And then came the Michael Frayn play, Copenhagen. And then on, and on, and on. And pretty soon I was bringing in art work from Dali, and it all enriched the class. And the students loved it. So I think that's a long answer to your question.

INTERVIEWER: No, that's interesting. How many of the students are familiar with the works you present? Is this a pretty well educated group, or are most of these things new to them?

SADOWAY: You'd be surprised. When I teach five fold symmetry, I play something with 5/4 time. So I'll have something like Take Five by Dave Brubeck, and the students will come down after the lecture and-- different students respond to different stimuli, but whenever I play Take Five there'll be several students who come up to me after and they'll say, you know there's this one and it's got 5/4 time. Or you could play this one, or you could play that one. So they're getting it. And then sometimes I'll show something in film or what have you. They respond.

INTERVIEWER: So it's a way of actually opening communications with students in different paths. It's not just talking about chemistry, per se, but about music and art.

SADOWAY: Absolutely. And I think it's important for me to model that I value music, I value art. I respect history. So that they see that I'm not simply the chemistry guy. That I'm not a shallow, one-dimensional character. I have multiple dimensions. How shallow or deep I am, we can debate. I think it's important for them to see that.

I'll tell you a cute story. When I teach X-rays, one of the lectures, there's three lectures on X-rays. There's generation, their characterization, and how they're used in examining materials, X-ray diffraction analysis. So on the second lecture I play the opera, Aria, La Mamma Morta from Andrea Chenier, and I use the version that's one of the recordings of Maria Callas, So she finishes and then I ask, so what were we listening to? And of course they say, opera. And I say, well which opera? What are we listening to? And then I tell them about the verismo style.

Why do we play this? Because Giordano wrote Andrea Chenier in the fall of 1895 and it was premiered in the spring of 1896 at La Scala at precisely the same time that X-rays were taking the world by storm. Because X-rays were first discovered by Roentgen on November 8, 1895, and so these are two parallel times. OK, fine. And I tell them for those of you who hate opera, or think you hate opera, go and listen to this. This is opera for those of you.

So anyways, after the final exam one year this young lady comes to me and asks if she can claim her final exam. I give them back their finals if they want them. So we go down the hall to this room where I had the exams in a file cabinet and I'm standing there flipping through them, and she says to me, you know I've been listening to Andrea Chenier. And I said, that's great. So you love opera? She says, before you played what you did I had never heard opera. So here's a young lady who was obviously good at math and science in high school and somehow ends up at MIT, and somehow ends up in my class. What's the most important thing I taught her that fall? She has a latent interest of opera. And she'll have that for the rest of her life. Now that's worth the cost of an MIT education I would say.

INTERVIEWER: Did you ever think about pursuing a career in the humanities rather than science and engineering?

SADOWAY: Yes. When I was in high school I loved language. I grew up in Canada, so of course we learned French, but I also studied Latin. I loved Latin. I distinctly remember studying the University of Toronto course-- what they call calendar here --the course bulletin and looking at classics. And I also seriously contemplated music. But then I decided applied science. I didn't like engineering. The word engineering didn't sit well with me. Mercifully at the University of Toronto what we have here as the School of Engineering there is called the Faculty of Applied Science and Engineering. I said, I want to be at the cusp of science and engineering. Applied science. I thought that was good.

INTERVIEWER: Did you have a music minor or anything like that?

SADOWAY: No, no. I took piano lessons as a youngster and so on.

INTERVIEWER: If you find exactly the right piece of art and music for the course do you then keep using it, or do you keep turning them over? It sounds like part of fun is to find new matches.

SADOWAY: Yes, it is. There is some change, but in some instances if you have a really nice match I just leave it in place.

INTERVIEWER: It's sometimes said that being known for spectacular teaching is the kiss of death in a research institution, but you've won tenure and you've made it to full professor with a named chair. Do you think there are real trade offs?

SADOWAY: Oh sure, sure. I mean there's only so much time in the day. But a career spans decades. So the way I've handled things was I dedicated myself to my teaching even at the beginning. I was teaching core graduate class materials science, and had about 40 students every year. In the spring and the fall I'd take recitation of 3.091. That still allowed me enough time to develop a research program that was strong enough to cross the divide and make tenure. But after I got tenure, actually I really took a big step back and re-oriented my research and re-oriented my teaching.

In other words saying, OK so now that they've agreed to keep me, now I'm going to parlay the security that tenure offers into wholesale remaking of what I'm doing both in teaching and research in such a way as to take greater risks. So even if I fail, it's not going to be, well this person isn't worth keeping here. But rather we've already established that he's made the cut but let's really reach for something that's greater.

INTERVIEWER: Do you have advice for young professors about how to think about the balance between teaching and research? Or advice on teaching, generally?

SADOWAY: Sure, I would say that you have to make sure that the research products are strong enough that you will be able to advance your career. And those are words that are carefully chosen. It's not that Caesar's wife must be virtuous, she must be seen to be virtuous. So whether that means you've got to publish your results, or you've got to get out into the world and be seen at conferences so that your reputation will grow. Then as far as teaching, be attentive to your teaching. Do a good enough job that you can get-- you see, the nice thing about teaching is that you can get almost instant recognition because the semester ends, course evaluations are available within typically a month.

And so I tell junior faculty to do a decent job when they first set out. Because you'll get a quick feedback and you can be instantly recognized as, well at least she can teach. That's good. Now how's the research coming? But then don't go overboard. Don't be obsessive and say, gee maybe I could fix this-- it's a balancing act.

INTERVIEWER: Going back to the 3.091 structure. You introduced a contest into the class at some point?

SADOWAY: Yes.

INTERVIEWER: Tell us about that.

SADOWAY: At one point, rather early in the semester, I require them to memorize the periodic table. When I first announced this, some of my colleagues called me up and said, are you mad? I thought rote learning went out with the Victorians? And I said, I think every educated person needs to know that cesium lies under rubidium. So I'm not going to ask them to learn the lanthanides and the actinides, but the S, P, and, D block elements, yes. I'm going to give them a blank periodic table and they're going to have to write the one or two letter abbreviations of those elements.

So there was some grumbling, but we put it into play and the students had 10 minutes to do this and they were all done in about three. As fast as their hands could write they filled out all these things. And then there was a sense of pride associated with it. And in then the subsequent years they would tyrannize the new freshmen. Sadoway is going to make you learn the periodic table, and we learned it so you can learn it, too.

So then not to dismiss the lanthanides and actinides I just said well we'll have a contest for mnemonics so that you could name the lanthanide series or the actinide series. And so they'd give me things like Lazy College Professors Never Cease To Produce. So, lanthanum, cerium, praseodymium, and so on. And every once in awhile you get a surprise.

Some time in the last 10 years a youngster turned in an Elizabethan sonnet. An Elizabethan sonnet contains 14 lines. There are 14 F electrons, there are 14 lanthanides and there are 14 actinide elements. And this was a piece that had three verses, four lines each, and a rhyming couplet at the end. And the first word of each line had the two letters, either adjacent or sometimes with a vowel in between. I just remember for samarium he had smelting. And he knew I was a metallurgist. I showed this to Janet Sonenberg who's on the literature faculty, and she got back to me a day or two later and said this is actually quite good. And by the way, it was written in homage to the Shakespearean sonnet number 57 because lanthanum, was element 57. I mean everything was just neatly done.

I've had some videos come in. This past year a gal did a karaoke to The Sound of Music doe, a deer, a female deer-- she does the entire periodic table. They really get into it. During the Friday of the parents weekend, when the parents are in town I present the awards to the students and it's great fun. And it just humanizes the class, and it's not all work and problem sets and so on. I don't think it diminishes from the learning, and it doesn't bring lack of respect for me that I've just turned it into a circus of games and stand up comedy for me. I think there's a lot of learning there.

INTERVIEWER: Do you have any idea what your poet is doing now?

SADOWAY: I don't know. I don't know. INTERVIEWER: One other touch in the class that people point to is that you come dressed in a tuxedo for one of your classes.

SADOWAY: Yes. This is the last lecture. At the very last lecture, as you know when the semester is drawing to a close, there are rules at MIT about homework assignments and so on. If there's a final exam there can be no homework assigned during the last week. And that stretch from Thanksgiving to the end of the first semester is really difficult for the students. They really should take some exams and then go home for Thanksgiving and don't come back until New Years or something.

But anyway, so here they are, and so the subject matter, the very last major topic is phase diagrams. I have a lecture on unary phase diagrams and I bring in some liquid nitrogen and we have some fun with that. The second lecture involves binary phase diagrams and so we play with ouzo and water and so on. And then the last lecture I call my champagne lecture, because I teach them how champagne is made. And it relies upon the knowledge of two phase diagrams. One is ethanol-water for the champagne, and then for cooling the neck of the champagne bottle you have to know sodium chloride and water. So I show them both of these phase diagrams and then we design the process by which champagne is made. And so I wear a tuxedo for that lecture and I finish the formal part of the lesson. And then I talk about the final exam and I make some parting observations about semester. Towards the end of that reflective part I open the champagne having taught them how to chill the champagne properly.

So every 3.091 student knows that there are six turns of the wire basket in order to take the cap off the champagne bottle. I open the champagne and I drink a toast to the class. I even bring a bouquet of roses and everything is very elegant. And they remember. I've had students come up and ask me about champagne. And is that so bad?

INTERVIEWER: Sounds like you're getting into charm school before IAP.

SADOWAY: There's an element of that, I suppose. I'm not going to push back from that.

INTERVIEWER: You seem to like to surprise your students, too, to keep them off balance. One Alum on some kind of blog was recalling a class that he took with you in chemical metallurgy, which wasn't 3.091, in which you ask, what was the most important variable in steel making? And apparently the students gave you all sorts of technical answers and tried to outdo each other, and you shook your head and said?

SADOWAY: I turned to the chalk board and I drew a dollar sign.

INTERVIEWER: Why don't you explain.

SADOWAY: I can't really remember. Well I don't know, perhaps you've got some more information on it. I'm drawing a blank on the exact timing.

INTERVIEWER: You said that if US Steel stopped making money when they made steel, they were going to stop making steel. And this was a bit of economics being meshed with the metallurgy. So we had the arts, and now we have the social sciences.

SADOWAY: Well I think that, I guess the way I look at teaching is that when I look at 3.091, it's not a chemistry class, it's a chemistry centered class. So 3.03, which was the course number of this particular subject, was chemical metallurgy, but the students need to know something about the economics of metal production. I thought it was perfectly legitimate to introduce this into the class. And they were fascinated by it. Evidently it stuck with this one fellow who managed to blog about it.

INTERVIEWER: I think it was one of the alumni association websites or something like that. But he was obviously struck by it and he remembered it. It was some years ago. I don't know how long, exactly, but there he was talking about yet another one of your classes.

Let's go back to talk about your path prior to MIT. Where were you born? Where did you grow up? What were you like as a kid?

SADOWAY: I was born in Toronto and my parents moved to Oshawa when I was three years old.

INTERVIEWER: To where?

SADOWAY: Oshawa. I guess today it's about 160,000 people. In those days it was probably 40,000-50,000 people. It's the home of General Motors of Canada. So it's an auto town. Blue collar town. All of the feeder industries, glass, you name it. Everything you need to build a car is in that area.

And my parents owned a motel. Small motel. When I was first born, my father was a co owner of a hotel in Toronto, but it was it basically a tavern. And then he and his partner decided to sell and move out of Toronto. One of them went to Windsor and my father went to Oshawa. The other interesting thing was that I didn't speak English until I was three years old.

My parents were both of Ukrainian descent. My father was born in Canada, my mother came from Ukraine when she was probably two years old. So they lived with my mother's parents at the time, so I spoke only Ukrainian. And when we moved to Oshawa I learned English over the summer of 1953. It probably took me a couple of months to learn English and then by the time I got to kindergarten I was fine. You can tell I still retain some thick Slavic accent. Probably not. The interesting thing is that I was in Ukraine in 1990 as a guest of the Academy of Sciences in Kiev, and there were some social settings in which people might walk in and not know who I was. And they would hear me speaking and they would identify me with the region of Ukraine from which my grandparents came. So even though my vocabulary might shrink because I don't use the language, after a week I could give a lecture on spectroscopy and molten salts. But the accent is pristine late 19th century Galatian dialect, which is what my grandparents spoke.

I grew up in Oshawa and not being of Anglo-Saxon extraction, growing up in a blue-collar auto town, it had its challenges. I mean, when boys found out that I took piano lessons I got the tar beaten out of me and stuff like that. I played hockey but quickly came to the realization that my goal tending skills weren't good enough to get me to the Boston Bruins. Bobby Orr and I are the same age and Bobby Orr was in high school and in Oshawa at the same time I was in high school.

So I decided if I were ever going to leave Oshawa, and boy I wanted to leave Oshawa, I was going to have to study my way out. And so maybe that accounts for my love of education because it really was the escalator. The social escalator.

INTERVIEWER: Did you ever work during the summers for General Motors?

SADOWAY: Yes. I worked one summer in the purchasing department. But I did other odd jobs. I worked one summer installing swimming pools. That was hard labor. And then I applied to the University of Toronto and went in to the program called engineering science, which was based on MIT. It was established right after World War 2 by some people who had studied at MIT. So I felt as though I got an MIT education at a Toronto price. And I was well served by it.

INTERVIEWER: But it sounds like the interest in science and math was partly interest and partly practical?

SADOWAY: Yes, I think that's fair to say. I think I was influenced by teachers. I think if I sit here long enough I'll recall some pivotal moment in high school where I said, science is really cool, that's what I want to do. But as we talked earlier, I could have gone into classics, I could have gone into music. So I think there may be a practical element. I think maybe my father would have had something to say if I'd told him, dad I'm going to go off to college and I'm going to study the classics.

INTERVIEWER: You've never tried to make a better hockey stick, though.

SADOWAY: I used to repair hockey sticks, though. I used to repair them.

INTERVIEWER: Was the University of Toronto where the best students went?

SADOWAY: Yes. In Canada I would say, some people think McGill is good, there are a lot of them around here, but I disagree. I think Toronto was the was a place to go when I was in school. As I say, the engineering science program there was really top notch and I think I got off to a good start.

INTERVIEWER: What excited you about materials science and engineering rather than other types of science?

SADOWAY: In high school I'd already started to take a shine to chemistry. Maybe because it's less precise. The math has got to be right. And the physics could be mathematically modeled quite nicely. Especially once you knew calculus you could do all of Newtonian mechanics. But chemistry, no. Chemistry required some visceral sense, some intuition. And I liked that. When I went off to college I thought I was going to major in chemical engineering. In Toronto, still into the late 60s, it was the old MIT model. It was two years general and then major in the third year. So we all had to take several semesters of chemistry and one was organic chemistry. And I disliked organic chemistry.

Chemical engineering, in those days, was largely petrochemistry. So where to find an expression for applied chemistry but not the chemistry of carbon? Extractive metallurgy. How to take ore and turn it into metal. And so that's how I found myself in what was, in those days, metallurgy. Material science was just in its formative stages. It was all metallurgy with some parenthetical remarks about ceramics. But I knew nothing about polymers until I came to MIT. And semi conductors for that matter. My knowledge was basically metallurgy.

INTERVIEWER: That's a good base.

SADOWAY: It's a good start.

INTERVIEWER: How much has the field changed since you entered it? Do you think it has changed more than most fields, or are most technological disciplines changing rapidly.

SADOWAY: I think materials science-- perhaps biology is the only one that I could imagine that's changed as much. And interestingly enough, what's the difference between biology when I was a kid and biology today? Today it's called molecular biology. Well what is molecular? Molecular is chemistry. So it's now gone to its chemical routes. I mean all the stuff about information and so on-- absolutely fascinating. But what is the mechanism of coding that information? It is chemical bonds along the back bone. It is all chemistry.

You know Rutherford was very outspoken, a colorful character. He was one of 10 children and grew up on a sheep farm in New Zealand. They once asked him, well when you model the atom, you've got the electron and you've got the nucleus, and you've talked about the movement of the electrons. You don't talk about the movement of the nucleus in your model. And he says, "when an elephant has fleas, it's the fleas that do the jumping." Well I lost my train of thought, so you have to bring me back to where I was. I knew there was some connection with Rutherford, but--

INTERVIEWER: We were talking about the change in the different fields--

SADOWAY: Change. What I would do if I were to pay homage to Rutherford I'd say parenthetically with reference to the comment I made about molecular biology-- Rutherford said, "all of science can be divided into two categories-- physics and stamp collecting." And so I would say he was close. I think it's chemistry and stamp collecting.

So materials science has changed a lot. It started with metals and metallurgy. The extraction and then, once you've got the virgin metal, how to combine it with other models and alloys to get alloys with different properties. Higher strength, higher toughness, what have you. But to make the metal the high temperature you needed to know something about containment. So that meant bricks, which meant ceramics. So there was always an element of ceramics that went with metallurgy.

And then in the 50s when along came silicon as the lead material in what ultimately became integrated circuits-- in the 50s it was still transistors, discreet transistors --how to extract silicon. Well silicon, even though it's a semi conductor, as a liquid it's metal. And the production of silicon is metallurgy. And so there was this natural growth from metallurgy to the production of silicon and so on, that then was sensible for the field.

And then the analogy to alloy development, where you take aluminum and you add some magnesium, and the next thing you know you've got a metal that you can make beverage containers out of. Well you start with a piece of silicon and you dope it with phosphorus, and you dope it with boron, well that's alloy development. And so the analogy there brought semi conductors under the tent, or into the tent. So now we've got metals, ceramics, and semi conductors. And then at MIT came the first successful attempt to bring in polymers. Polymers, up until that time, had been largely handled by chemistry or chemical engineering departments. And that was about the synthesis of the polymers. But what materials science had come to, really become the primary expositor of, is this notion that if you change the atomic arrangements you'll change the properties.

And so, well, let's do the same to polymers. So we can take high density polyethylene and low density polyethylene. Chemical composition identical. But by changing the nature of the backbone, without changing the chemical composition, we get radically different properties. From the hard milk jug you have the stretchable food seal. Same material. So it was here at MIT under Walter Owen, who actually was the department head who hired me, that the decision was made that we're going to integrate polymers.

I'm told at the time there were some old school metallurgists who bristled at the idea. That it was too different and it wouldn't work. And of course they would make it their mission to see that it didn't work. And Walter made it his mission to see that it did work, and it did.

INTERVIEWER: So you mentioned earlier that somewhere during college maybe, you began to think about teaching college and remaining an academe. How did you begin to plan out your career, or what you needed to do next?

SADOWAY: I've never been very good at long range planning. I think my career has been a series of near term adjustments. So at some point I decided, well if you really want to teach college you're going to need a PhD, so I continued in Toronto. I pursued graduate study because I was taken by one of my faculty in the undergraduate program there. And I ended up staying and doing a PhD with him. And then I realized that I couldn't go directly from a PhD to a faculty position, I needed to round out my education with a postdoc.

I won a NATO fellowship which allowed me to go anywhere in the NATO alliance and decided to come to MIT to work for the late Julian Szekely who was really avant garde in that he was bringing notions of how you model transport phenomena that were common to chemical engineers but unknown to metallurgists. He'd only recently come to MIT. He'd been at SUNY Buffalo and then, I think around '75 had come to MIT as a full professor. So I chose to come here to postdoc with him and the plan was to spend a year or two postdoc-ing with Julian, fatten up my resume, and then try to find a teaching position back in Canada. And while I was here postdoc-ing a vacancy came up on this faculty. They were actually looking for a physical metallurgist. Someone that would be involved in alloy design and so on. Julian came to me and said, I think you ought to apply for this position. I said, this is MIT. He said, I think you have some fine qualities, so go ahead. You're being too Canadian. So I applied for the position and was offered the job. So that's how I ended up here on the faculty.

INTERVIEWER: What did you do your dissertation on?

SADOWAY: My dissertation was in the chemistry of the separation of niobium and tantalum. These are two elements that lie below vanadium. They're found together in nature thanks to the lanthanide contraction. They are chemically almost twins even though they have rather different atomic masses. There are certain nuclear applications where even though niobium and tantalum are chemically very similar, in a nuclear setting they are poles apart. One of them has a very high neutron capture cross section, and the other one as a very low neutron capture cross section. And so if you're going to use these as alloying elements for parts of a nuclear reactor, you want them to be either opaque or transparent but not a mix of both. And so I worked on a process to separate the two by forming compounds where the difference in the two compounds, the difference in the vapor pressures of the two compounds, was enough that by fractional distillation you could get some reasonable separation efficiencies. So the thesis involved preparing the compounds, measuring their physical properties, X-ray diffraction, et cetera, et cetera, and then modeling the process.

INTERVIEWER: How did you choose the topic?

SADOWAY: There had been some work in the lab that I was working in on zirconium and hafnium which are both group four elements. And same thing-- zirconium is transparent to thermal neutrons, hafnium is almost a complete block to thermal neutrons. I thought, well, you make zirconium-niobium alloys, and so tantalum contamination in niobium would ruin the alloy. So why not try the niobium-tantalum chemistry. Plus I figured there's a wealth of information on the vapor pressure behavior of the chlorides of zirconium and hafnium. That ought to get me off to a roaring start. It terms out the chemistries of niobium and tantalum are very different from the chemistries of zirconium and hafnium so it was a struggle but I learned a lot.

INTERVIEWER: Did you continue on that work when you got to MIT or did you switch gears?

SADOWAY: I switched gears. I think there was one small piece of follow on work. It's normal for people, when they're starting out, if there's some loose ends to still tie up after the PhD. There might be a little bit of follow on work. Well maybe I shouldn't say that. There may be some people that continue to use their PhD as a platform for a long time. I don't mean that in a disparaging way. It depends on the topic.

But I figured I'd said what needed to be said about the niobium and tantalum, and then started to move into electrochemistry because I wanted to develop this whole area of the electrochemical extraction of metals. This is how aluminum is made, by an electrolytic process. Magnesium is made by an electrolytic process. And I want to look at maybe extracting tantalum, titanium, and going farther. In the late 70s and early 80s there was still interest in the domestic aluminum industry and the fundamental electric chemistry behind the process. That was also a motivation to study the basic electrochemistry there.

INTERVIEWER: Do you remember your first impressions of MIT?

SADOWAY: Oh yes. I remember when I first arrived and I walked up the steps from that cross walk at 77 and looked up at those pillars and thought, well you've really done it now. This is high stakes. No more big fish in a small pond. This is the real deal. And the early days were very heady. I mean, to be surrounded with super bright people. I was postdoc-ing with Julian and the kinds of people that would come to visit him was just a different world from the University of Toronto.

INTERVIEWER: Which is a major research university.

SADOWAY: Yes, and they were good people. We had good people there and people came, but at MIT it was just at a different level. I think one of the first things that impressed me was the number of industrial people that came to MIT. We didn't see quite so much of that in Toronto. You know, academicians would come, but the industrial connections here were quite impressive and continue to be.

INTERVIEWER: What do the industrial people come for?

SADOWAY: They come for knowledge. They wanted to interact with the faculty because, in those days, American industry was still interested in understanding how their processes worked. Interested in how to optimize their processes. And they were also coming to meet students. Because they were trying to get acquainted with some of the best minds that might, down the road, become potential hires. And they realized that one way to identify top students is to form relationships with top faculty who might say, I've got a really good student. He or she's going to be finishing in the next year. Sometime when you're out this way you might want to swing by and take this personal lunch and get a sense of them.

INTERVIEWER: And these are mostly people who work in the R&D arms of industry or not?

SADOWAY: Yes. Mostly, but not exclusively. Julian hobnobbed with even the executive class. And he would tell them if he thought some of their decisions were ill advised. He used stronger language.

INTERVIEWER: And these were executives who had come up through the science and engineering ends of their companies and understood it?

SADOWAY: Yes. Until probably the 1980s. If you were to look at say, 1955, I'm willing to bet the president of US Steel was a metallurgist and the president of Alcoa was a metallurgist. By 1985 I bet you could put a bar of steel and a bar of aluminum in front of the president of Alcoa and he probably couldn't tell the difference between the two. So in those days, yes, the VP would be somebody who had come through the ranks of R&D and made executive decisions but was interested in fundamentals.

INTERVIEWER: And has there been a shift, then, in the types of executives or industrial people who come through? Are you seeing more people from other countries who place more value, perhaps, on industrial production?

SADOWAY: Yes, that's correct. I mean, the metals industry has shifted. There's very little basic R&D done in the United States. I'm hopeful that the pendulum might swing back, but yes we're getting visitors from East Asia, from China now, from Europe, from South America, too.

INTERVIEWER: And government? Did people from DARPA or any other agencies tend to come through?

SADOWAY: Oh, sure. Absolutely. But also the policy arms of government. The year that I postdoc-ed with Julian he was engaged by the Office of Technology Assessment to host a conference for OTA and the topic was the future of the American steel industry. I was a postdoc and so I ended up in a supporting role which was ideal for me because I ended up being sort of the intellectual gopher. I interacted with these people that were coming from steel companies all over North America and from Europe. And it was exciting. We had these government officials from Washington that were keenly interested in the outcome of this meeting which lasted for a day and a half or something.

INTERVIEWER: Did that become the major thing you did as a postdoc or did you have other research? And how did you choose that?

SADOWAY: No, I had research, laboratory research. Julian's strength was mathematical modeling of transport phenomena and one of the processes he was modeling involved-- it's a device called a tundish. It's a large cauldron. Might be 60 tons of molten iron in it and alloying additions are made to the molten iron. But you have to stir and you can't use a spoon. So one of the means of stirring is electromagnetic induction. There are coils that go around this cauldron and the magnetic field causes the iron to go into circulation. Julian had done some modeling of it. Remember, this was 1977. There were no personal computers. The equations could be written, but to solve them required pencil and paper. I mean, there were some mainframes but you remember the card decks that were this long? You couldn't do that. It was all here.

So anyways, I said to Julian, have you ever done any experiments to see what the flows might be? So I took my expertise from Toronto in high temperature physical chemistry and married it to electromagnetics and developed an experiment which we used copper tubing that was coiled around a beaker made of laboratory glass and I melted some salts that, on melting, produce a clear, colorless liquid. And then looked at the effects of magnetic fields on how this stirred because obviously you can't see inside liquid metal. So the molten salts have some conductivity that's intermediate between a metal and say, water. In water the connectivity is too low to give you meaningful results.

There was one paper that came out of that. It was fluid flow measurements in electromagnetically driven molten salts. So the steel making conference was one event and I think it happened in the spring. So by then I was fairly far along with my experiments. It was right around that time that this faculty search was in full swing. It's all a jumble to me now.

INTERVIEWER: But it was fixed, right? You had a mentor who was pushing?

SADOWAY: Oh no, not at all. Not at all. In fact, if anything, the department head, Walter Owen, who did agree to hire me, was himself a physical metallurgist. The search clearly specified someone that was from the complementary side of metallurgy from me. So I think I had some persuading ahead of me.

INTERVIEWER: But you succeeded.

SADOWAY: Yes.

INTERVIEWER: How much has MIT changed since you've been here?

SADOWAY: In some ways not at all, in other ways tremendously. If you walk down the Infinite Corridor it's almost imperceptible. You'll hear alums come who graduated in the 50s and they say, oh it's great to be back at Tech. Nothing's changed. You kind of wince.

But other things have changed. I think at some level it's become more corporate. People are far busier. I used to have an office on the Infinite Corridor. I was in building eight, room 109, which is now an undergraduate teaching laboratory for materials science. So I vacated my space in order to allow for the building of those labs.

I'm glad we have them, but in the early 80s I would sit in my office and I'd have the door open. People would walk down the hall and sometimes pop in and just sit down and we'd chat for 15-20 minutes and an idea would emerge. Now people don't sit with their doors open. And if somebody pokes their head into your office you almost look at them and say, do we have an appointment? What are you doing here? You're sort of looking nervously at your computer screen and say, I've got to get this done, and I'd love to talk, but--

INTERVIEWER: You weren't that unusual back then in keeping your door open?

SADOWAY: I don't think so. I mean if I wanted to talk to-- I joined the faculty, my previous mentor, Julian Szekely was still on the faculty and if I wanted to talk to Julian I didn't phone him. I mean, we didn't have email. We had a black phone with a rotary dial. I didn't phone him, I just walked down a corridor, made a left turn and started walking down the first floor of building four and walked into his office.

INTERVIEWER: So what's driving the change? What's behind it?

SADOWAY: I think people are much busier. I think in those days it was easier to get funded and the funding was longer term. So people were more relaxed about resource procurement and maintaining the funds that you need for a research program. Things were just a lot simpler. People were, I think, more relaxed.

INTERVIEWER: Do you think MIT's role in the world has changed much over the time you've been here?

SADOWAY: That's a tough question. I think MIT always had this special role. It was a role of, if you want a real, unbiased technical answer you go to MIT. Certainly over the time period we're talking about, from the 70s, I can't talk about pre World War II, but certainly from the 70s on, the whole business of spinning out technologies and playing an advisory role in government. Even playing a role in government. We've had several people serve as undersecretary of energy, and going back to Bob Siemens, who was the first director of the Atomic Energy Agency and so on. MIT has always had a role to play, and a leadership role. So I think that's one of the good things that's remained constant.

INTERVIEWER: Do you think your undergraduate students or graduate students have changed much?

SADOWAY: Well they've changed in so far as there's a generational change. The Gen-Xers are different from the boomers, et cetera, et cetera. But I think the core is still there, the technology focus and high ambition and so on. I would say that perhaps today's students may become a little bit more well rounded than the ones in the late 70s, early 80s. I think they were narrower.

INTERVIEWER: And do you think that's intentional on the part of MIT in its admissions office? You've sat in on admissions committee discussions as a faculty member of their committee--

SADOWAY: I can only speak from the time that I was there. And from that time forward I think, based on my interactions with the students in 3.091, that we look at both the breadth and the depth. People who are absolutely brilliant in their math or their physics but score poorly on the personal index have a difficult time of being admitted here. Now, I was not part of admissions going back to the late 70s, so I don't know whether the narrowness was simply a sign of the times-- whether students going through high school ended up being channeled early they didn't-- I mean I certainly had to study history and literature in high school, so maybe these people missed a day of class or something. I can't explain it.

INTERVIEWER: Or didn't retain it--

SADOWAY: Or didn't retain it, or somehow felt that it was not important. I can't answer the question. I can only tell you that this is the difference that I notice. You asked earlier about when I talk about the music, the art, the literature, do they get the references. By and large they do.

INTERVIEWER: I think something like three quarters of them enter with fairly high level music preparation experience, so I don't know about art and history, but the music is certainly there. Was it in any way difficult for you to make the move from Canada to the United States? Did you feel like the cultures were very similar or not so similar?

SADOWAY: There's a lot of similarities. Remember I wasn't coming from rural Canada to rural United States. I was in Toronto and it's a large Cosmopolitan city and so coming to Boston-- actually Boston is smaller than Toronto. At some level I felt Boston was kind of compact. It was exciting for me. It was an exciting time. It was fresh, it was different, but similar enough.

The main difference that I recall, and it's probably still accurate, is that I think in the United States there is a much more intense dynamic at work here in trying to understand what a democracy is. It's not as though it was established and it just runs. There's always something going on at the Supreme Court to try to settle, what happens if such and such? And I love that. It's still in the process. You don't have that in Canada. The other thing is the healthy sort of challenge or disregard. I don't know how to put it, but the level of reliance on government in the United States is much lower than it is in Canada.

You know you're talking to a Canadian because after about 15 minutes, at some point, the Canadian will say the government ought to--. In the United States you don't hear that. And I think it comes from the heritage. America was founded in revolution against the crown. Canada was established in loyalty to the crown. The head of state of Canada is the Queen. When I was a child the union jack flew from the flag pole.

INTERVIEWER: You've talked about the benefits of the corporate representatives coming through your labs and your departments. On the other hand, you also talked kind of in a more negative way about MIT being more corporate now. I think they're two different things you had in mind. I wonder if you'll elaborate a little on what you meant by the more corporate, separate from the corporate involvement.

SADOWAY: OK, so when I say corporate involvement, I mean the industrial involvement. So engineering is stewardship of the earth's resources as applied science, and so these are the people that make money by practicing the art. And so if I want to study the fundamentals of smelting aluminum, it would behoove me to interact with people that actually produce the stuff and sell it. If they have a bad day they can't sell their product. It's different from me having a bad day and I got one of the homework solutions wrong so we'll correct it tomorrow. So that's the sense that I mean the corporate involvement. It's really the industrial practice piece.

The corporate when I referred to it in a slightly negative way is the sort of formality associated with the structure of MIT. One of the other things that struck me when I got here is it's flat as an organization. It's flat. People answer their own phones. I've had people phone me and say, I'd like to speak to professor Sadoway. I say you got him. They say, no, is professor Sadoway in? I say, you're speaking to him. They can't believe you pick up your own phone.

There was a time when-- mercifully it happens very rarely --but there was a student in serious academic difficulty and was actually going to be expelled. I was on the telephone call with a colleague of mine up in Halifax in about '85-'86. We had the rotary phone, but it had two lines with the push buttons and the light glowing for the second line. I said, George let me just put you on hold for a second. I don't know what came over me, because we couldn't tell who the number was that was calling. Hello Don? Yes? This is Paul Gray, Paul Gray was the president of MIT and was phoning me because he was about to meet with this person who he was going to expel. And I was the person's registration officer and adviser. Now, this is the president of MIT and he's phoning me. He picks up his own phone and he dials my number and he waits for me to answer the phone. Any place else it would have been a secretary, typically a woman, that would have said, Dr. Sadoway, I'm calling for Dr. Gray. Please hold for Dr. Gray. And then I wait. But not at MIT.

One time I got a phone call when Gerry Wilson was dean of engineering. I pick up the phone and he says, Don? Yes. This is Gerry Wilson from the dean's office. I said you're not from the dean's office, you are the dean! I love that about the place. Well, it's not quite as-- if you look at how many vice presidents and assistants to the vice president that we have, compared to what we had before, boy.

INTERVIEWER: Does that affect your research or teaching much, or is it just sort of there?

SADOWAY: Well it affects my research, because I think ultimately it must have some impact on the overhead rate. But no, nobody cares enough about my teaching to bother me about my teaching. That's the other nice thing about teaching is that I can do anything I want in that room as long as it's in good taste and the students don't go to Mary Rowe and get me on the carpet over it, I can do anything I want.

INTERVIEWER: When you were a junior faculty member, how involved were you with the rest of the institute beyond your department? Where you in a silo or did you--

SADOWAY: Yes. I knew nothing. After I became a tenured faculty member I think I was starting to be tapped to serve on institute committees. Then I started meeting people from all over. And that's a rich experience. There's some fantastic people here and they're not all in my department. Surprise, surprise.

INTERVIEWER: Literature and theater arts?

SADOWAY: Exactly. The Sloan School, the School of Science. There are great people everywhere.

INTERVIEWER: On the corporate front, you were involved at one point in an interesting law suit involving magnesium.

SADOWAY: Yes.

INTERVIEWER: I don't know if you've done a lot of these law suits, but tell us about that one.

SADOWAY: From time to time I get called to act as an expert, sometimes in a patent infringement lawsuit, in this case I was called by the Justice Department. The US Justice Department was acting on behalf of the EPA to prosecute a magnesium smelter that was in violation of the law. In huge violation. They were polluting-- they weren't even hiding it, they were brazenly polluting. They claimed that they had an exemption that was provided by the law. They were in flagrant violation of the law, there was no doubt about it. And so, since I knew something about the primary smelting of magnesium-- I'd studied it, published a seminal review paper on magnesium --I was contacted.

At one point I had the chance to visit the smelter and walk through the operation and so on. And then be present at depositions where I was able to advise the attorneys working for the Justice Department what questions to ask of people who worked for the company. There were a number of times during that period where I felt really good about serving the public interest. There was major damage being done to the environment on the banks of the Great Salt Lake and in the soil and the marshes abutting it. They had to be stopped. And all the lawyers in Washington couldn't have done a thing. They needed the technical expertise. I think it's a legitimate activity on the part of a faculty member in the School of Engineering to serve the public interest on an occasion like this. I was glad to do it.

INTERVIEWER: About seven or eight years ago your department head, who was then I think Subra Suresh, asked you to lead a committee to develop a new undergraduate curriculum in materials science and engineering. Why was that committee formed and what did you do?

SADOWAY: Periodically we take a look, as I've mentioned earlier in the conversation, materials science has the undergone major changes over time and continues to grow. With nanotechnology and the merging of life science and materials science on one axis, there are new opportunities for materials scientists to act professionally, and we have to prepare our students accordingly. So curriculum that looked just ideal in 1982 maybe looks a little bit out of place in 2002. My department head, Gerd Ceder, evidently had some respect for my judgment. I'd been teaching 3.091 at the time and had some reputation for curricular innovation and so on. So he came to me and he said, would you lead an effort?

And he did it the MIT way. It wasn't democratic. It wasn't let's get everybody into a room and take a vote. It was, choose someone that you trust to do the job. And then he told me, choose your team. He didn't say, I'd like you to serve with x, y, and z. He said, pick three or four people to work with you and then I'd like you to report to the general faculty by such and such a date. And he turned me loose. I said, well what are the constraints? He said, none. I said, financial? He said, I'll worry about the money. You tell me how to teach this program. What should be in it, and how it should be taught.

So I got together with three or four of my colleagues that I thought were the most forward thinking and capable. I remember sitting with literally a note pad and a pen and drawing. I did this all graphically. OK, so you go from here, to here, to here, and then we put the lab in here. It was all time domain. This topic, and this topic, and then this activity and so on. Then brought it in front of the faculty and, long story short, one of my colleagues, Caroline Ross, was tapped to actually implement the program. So Caroline really put the program in place. But I was the one that did the initial sketches.

INTERVIEWER: How different was it?

SADOWAY: It was hugely different. The main difference was a high degree of laboratory activity. And what was different was instead of having lecture classes and lab classes that ran either in parallel or in a different semester, what I implemented was taking several of the key lecture classes, ganging them together, and then teaching that subject matter in a way that one faculty member knows what the other faculty member is doing. They move in parallel, and after three weeks they stop all lectures and then it's an entire week of intensive labs that integrates the subject matter from the two classes.

This starts in the sophomore year, the first year that students are majoring in materials science. And then they go back to the lectures, twin lectures another three weeks, and then stop and into the lab. So it's this inter-weaving of the labs as opposed to, there's the lab class over there, and the lab class instructor has got his or her agenda, and their struggles and the lecturers are over here, and they talk to each other over cocktails at the Christmas party but that's it. So this was really integrating to a very high degree. That was the main hallmark of the devised curriculum.

INTERVIEWER: It sounds very rational in theory. How does one rearrange other professors' lives and classrooms and so forth and make it happen? As you say, there was an implementation--

SADOWAY: Well, I think there was a period of discussion and we made sure that people had a chance to express themselves and voice criticism and express concerns. To the credit of my colleagues, we got enough buy in that if there was resistance, it's minor. And there were a lot of successes.

INTERVIEWER: In putting your committee together, was it hard to find people who-- no?

SADOWAY: No. They wanted to work.

INTERVIEWER: They were willing to devote this much time to re thinking something this big that could backfire and have everyone shooting at them? No.

SADOWAY: It didn't turn out that way. These were people that were younger than I am and had recently either been tenured or had just recently made full professor. They had a long run time and they saw this as freshening up the undergraduate program in a department where they had a long run time. So at some level it was serving the department, but at some level there was a good deal of self interest. The right mix. In other words, it wasn't pure altruism. I didn't expect them to just do this out of the good of their hearts, because they don't have all that time to give. It was just the right confluence of aligned interests.

INTERVIEWER: What did it mean for the department? Did it do anything for enrollment?

SADOWAY: Oh absolutely. Absolutely. You asked me earlier about the motivation. I avoided the real truth. Of course you have to take a look at the curriculum, but it wasn't just curriculum. There were concerns that perhaps people weren't devoting themselves to their teaching as students might expect them to do so. Enrollments were dropping. It's hard to separate the drop in enrollment in materials science from the ascendancy of the life sciences.

The departments that were clearly places-- remember we didn't have a biology major at that time period. Forgive me, not biology, the biological engineering. So there was no biological engineering major at that time. So people were looking for-- obviously people would go into biology, which was School of Science. But if they wanted applied biology, they'd look at chemical engineering, course 10, or they might look at mechanical engineering. And we were slow to adapt, and so we were losing students. With all of these cases, I think there's both a push and a pull.

INTERVIEWER: How did you work your way around that? I mean, the life sciences, or biotech, still exist. And yet you've seen enrollments grow.

SADOWAY: Well, part of our strategy was to give students the tools they need to be active in the life sciences. We successfully made the point that the life sciences today are molecular biology, which is the chemistry of it. And we played our strongest trump card, which is materials science as the font of knowledge that helps people understand how the manipulation of molecular architecture alters properties and performance, and even so in the life sciences. Obviously we've been successful, because our enrollments are so high that some of the labs are struggling to accommodate all of the students. We have the problem of an abundance of success.

INTERVIEWER: Have other materials science departments around the country done things like this, or were you at a leading edge?

SADOWAY: I would say we were at a leading edge. After we developed this program, I remember giving a presentation at a materials conference. There were other universities represented in this session. I wasn't the only speaker, so it was a session that might have had five or six presentations. Materials departments from other schools would present what they're doing in their undergraduate programs. And I can recall just being astonished at where they were in the evolution of the materials undergraduate programs. There were literally schools that were still teaching metallurgy and were proud of the fact that they were now broadening and doing some work in ceramics and semi conductors. They were where we were before the 1982 revision. That's where they were.

But, in fairness to them, MIT is special. The materials department here at MIT has enough faculty that it is capable of institutional completeness. And it can span the entire range of materials, from metals through ceramics, the polymers, the bio materials, and have enough bench strength to do justice to those various divisions. When you have 35 faculty, you can do this. If you have 15 faculty you can't. You have a concentration in semi conductors, or a concentration in ceramics, but your undergraduates are expecting to learn about the breadth of materials science. So it's very difficult for the those schools to compete.

INTERVIEWER: When you were talking about biotech before and molecular biology, actually, it sounded to me like if you were going to school today, maybe you would have been tempted to study that.

SADOWAY: Yes, yes. I'm fascinated by it.

INTERVIEWER: Have you moved in this direction in your research?

SADOWAY: No.

INTERVIEWER: Because some materials scientists have. I think Subra among them--

SADOWAY: Yes, Subra has. We've got a number of them. But I haven't, because there's something that fascinates me even more and it's the social imperative-- maybe that goes back to why I thought chemistry would be my calling, is because I didn't realize it, but there's a latent interest on my part in what Susan Hockfield enunciated at her inauguration, which is science in service of society. I think the biggest impact, just as I teach 3.091 for the biggest ripple effect, the biggest ripple effect in research in my opinion today is not in the life sciences, it is in energy. And that's why I choose not to follow, even though I find it fascinating. It's more important that we develop a battery that can store the grid than unravel the human genome or something like that. And I'll say that to Eric Lander and we'll have a laugh over it, but yes, I respect their work--

INTERVIEWER: So tell us about your quest to make a better battery. This has actually been a major research theme of yours.

SADOWAY: Right, so I started battery research at MIT in 1994. There was none at that time. There may have been in a long, long, much, much earlier time-- maybe before World War Two --but to the best of my knowledge there was no battery research. It came out of the fact that I was a teaching a class on technology and policy about air quality in the Los Angeles basin and I was invited to give some guest lectures about batteries because electric vehicles might be part of the solution.

Out of that experience came the invitation to go to Ford Motor Company in Dearborn, Michigan, and meet with the team that was working on an all electric vehicle back in 1994. It was called the Ford Echostar, it was a Ford Escort that had sodium sulfur batteries. I got to drive this car and I came back from Detroit just absolutely elated. I grew up in Oshawa and I loved cars, grew up in a car culture. This was an all electric car, and it was it was fast and it was silent. The only thing wrong with it was the batteries weren't good enough. They were too expensive, they weren't reliable enough.

So I got back, and I'd already made tenure, full professor, and so on. I was thinking, you're an electrochemist, why don't you do something about this? And I started reorienting my research. I kept the metal extraction piece because I was, by that time, looking at environmentally sound processes to replace the carbon intensive processes that are used to make metal today. So I wanted to keep that environmental peace going.

But the battery, that could enable all electric vehicles. It could electrify our transportation system, reduce our dependence on import petroleum, liberate our foreign policy, provide well paying jobs for Americans. It was win, win, win, win, all we need it was the battery. So that's how I got started. So I've continued to work on batteries for portable power. And then around three years ago one of my colleagues, Garrett Seder came to me-- maybe it was three, four years ago --it was around the time they were forming the MIT energy initiative. And he had served on one of the committees that was planning the initiative. He's a colleague of mine from materials science. He came to me and said, there's a really big problem out there that nobody's been able to get their arms around, and that's grid level storage. If you're going to ever see the day when solar or wind is going to become part of base load-- not talking about augmenting.

On a hot day like today we need extra power and if we're lucky and the sun's shining, all right so the photovoltaics can help us. But what happens after the sun goes down? So photovoltaics, wind, will never be part of base load unless we can capture that energy and have it available when the wind isn't blowing and the sun isn't shining. I say, with the right battery we can draw electricity from the sun even when the sun isn't shining. Now that's a different set of constraints. The battery that goes in your cell phone needs to be idiot proof because it goes in the hands of idiots. A battery that goes into a car has to be crash worthy. But a battery it's going to store the energy from a wind farm, it's not going to come into contact with the citizens. It's not going to be driving up and down the roads, so it doesn't have to be at body temperature. There's much more freedom in choice. We have to think about the problem differently.

So about four years ago I started thinking about grid level storage and now have a major research effort in batteries for what we call stationary applications. Whether it's to provide power for a hospital if you go in to a blackout, or to do whatever is needed to keep the grid from going down. Which could be things like load leveling, load following, frequency regulation. A host of different applications requiring batteries of different capability. But certainly different from the lithium ion battery that goes in your laptop computers. So that's another area of research.

INTERVIEWER: Do you have a time frame when you think it will be solved in some way? Is it a solvable problem, or is it just something where one gradually makes improvements a little bit here, a little bit here, a little bit here?

SADOWAY: I think history will judge that. I'm hopeful that it's not going to be a long, long time, because I'd like to see it happen in my lifetime. I think it's going to require some breakthrough thinking and I think we might have that in my lab right now. We've got some cells that are cycling quite nicely. Very exciting chemistry. And now we're looking at whether the idea is scalable. That is to say we can build small battery, can we build a really big battery? And the reason we have to build a big battery is that all the batteries we know right now are built in units that are about the size of your hand or smaller.

If we want to store the energy that comes from a wind farm or from the grid, we can't string together thousands of batteries each the size of a soda can. The costs are prohibitive. So we have to start thinking about building big batteries the way we build an aluminum smelter. This is the tie in with my metal production. You can take bauxite from one corner of the planet, petroleum from a second corner of the planet, cryolite from a third corner of the planet, put them into a smelter that has a capital cost of $5,000 an annual ton and shoot 13 kilowatt hours across the cell to make a kilogram of aluminum and it can do it for less than $.50 a pound. Now why can't we take the power, the economic power, of modern electoral metallurgy and apply it to battery design.

So that's the motivator behind this liquid metal battery that I'm working on. If my hunch is correct and we can scale up from the soda can to something the size of this studio that we're recording in, we change the world. Because then, imagine, you've got the ability to bring carbon free methods of generating electricity into the grid as base load. And then, in parallel, invent a battery that's capable of electrifying the vehicles. So you electrify the transportation fleet, you decarbonize the grid. I mean that's a new world.

INTERVIEWER: How do you organize a lab to create breakthrough science and engineering? Do you wake up every morning saying, do I have a new idea to push this forward today? Or do you come into the lab and say, OK, you're the postdocs, you're supposed to be the hot idea producers. How does that all work?

SADOWAY: My process, different people have a different way of doing it I suspect, but I have a very flat management structure. I hire good people and I give a lot of autonomy. And I teach them. I teach them to think about the problem the way I think about the problem. Once I know that they understand the real problem, then I just say you're smart, you can think your way through. And then we continue to have discussions and I sort of coach them along. The big breakthroughs, maybe that's my responsibility. I'm the one that's got to get the money and the resources and so on. I say, OK, so I'm the coach but you're going to put the puck in the net. If I can use a hockey analogy.

INTERVIEWER: Are undergraduates interested in this?

SADOWAY: Absolutely. In fact, I hire UROPs, the undergraduate students, and I only hire freshman. And I hire them out of 3.091. And they're fantastic. They love it. And I've got four of them working in my lab this summer, right now. They started with me in the spring semester.

INTERVIEWER: And do they stay with it for two, or three, or four years?

SADOWAY: Some do, and others want to gain experience working with other faculty and I encourage them to do so. I don't chase them out of my lab, but at the same time if they want to get exposed to other faculty I encourage them to get a UROP in a different lab.

INTERVIEWER: Are there many other labs around the country and around the world, that are now beginning to focus on battery technology?

SADOWAY: Oh yes. Yes. As the funding grows, you're seeing more academic research. I find that positive because we need a big community. It's a tough problem. It's not an issue to invent a battery. The issue is to invent a cheap battery.

INTERVIEWER: So this is the grid problem you're talking about?

SADOWAY: No, I'm talking about batteries for cars. Energy storage is huge.

INTERVIEWER: The original research plus the newer-- but it sounds like they were two separate projects because they had two sets of constraints.

SADOWAY: Correct. They are very different problems.

INTERVIEWER: But they work next to each other?

SADOWAY: Oh yes. In our group meetings we get 25 people in a group meeting and we learn from one another. The metals extraction people learn from the battery people, and the battery people learn from the metals extraction. So I view it as sort of mental gymnastics. Keep their brains working and then all of a sudden one day they'll see ideas that are transferable and move from outside the field.

INTERVIEWER: You just have to put the right piece of music on.

SADOWAY: Maybe. Maybe.

INTERVIEWER: The physics department, coming back to teaching, has moved away from large lectures, saying that students weren't really learning well. Do you think you could have made physics lectures more effective? Or is there something different about teaching physics and teaching solid state chemistry?

SADOWAY: Let's see. Well, there's two pieces to that answer. The physics department has embraced this technology enabled active learning. TEAL is the acronym. This was done at least 10 years earlier at Rensselaer. They called it studio physics. Not every student has the same learning mode. Some people are visual learners, some are tactile learners, some are capable of sitting for an hour and listening, and others get up and fidget, and so on.

So it doesn't surprise me that the physics department finds that some people learn by sitting at a table in groups of three and so on. I don't have that luxury because if you're teaching Newtonian mechanics, you're dealing with inert objects that will impact one another and you can measure velocities and so on and so forth. Or electricity and magnetism you can measure forces. You can't have studio chemistry. You can't have nine people seated around a table with open vessels and chemical reactions taking place. So it's a non starter.

So people who talk about TEAL and say it's the way to go, I say well I can't use that information. Now as far as whether people learn in big lectures, I would dispute that. I would say that some of the finest lectures I've ever seen were delivered by Walter Lewin who was a lone individual with a piece of chalk. He used demonstrations and the students loved him, and I think they learned a lot from Walter. I don't want to say bad things about the direction the physics department has taken, but I do believe that it still is possible if you have a lecturer that's engaging and the subject matter is solid. Students will learn from a lecture format.

INTERVIEWER: He's another teaching superstar. Do you and he ever sit and talk about teaching?

SADOWAY: We've had kind things to say about each other. We'll see each other at some function and we always end up chatting together.

INTERVIEWER: Have you sat in on any of his classes?

SADOWAY: I've seen his classes on video, and actually he gave a lecture during IAP that I went to. His lecture was about his love of art. He's quite a collector and he's very knowledgeable about the history of modern art. It was a thrill to hear Walter Lewin explain the evolution of modern art. He's really a polymath and I have a very high regard for him and a lot of affection for him.

INTERVIEWER: So if you're going to keep lecturing, is MIT going to give you a lecture hall that you can love?

SADOWAY: I think 10-250 is going to be the facility, take it or leave it.

INTERVIEWER: But it's not big enough to hold the crowds that want to attend your course.

SADOWAY: These days the number of people enrolled in 3.091 exceeds the seating capacity. And if the Cambridge fire marshal came there on a particular day we might be in trouble. So yes, there is a need for something larger. We've solved the problem in the last several years by piping a video feed into a second room. When I was originally told that this was going to be the case, I was saddened by the fact that students might have to sit in another room. But it turns out that they self select and they like going to the other room. About 50 of them go to the other room because in my class I won't allow people to eat or drink. So I'm told by-- there are a few TAs that sit in there to make sure it's not pandemonium --and I'm told that students go there and they've got their coffee and doughnuts.

INTERVIEWER: Do they talk to each other?

SADOWAY: They're not allowed to make too much noise, but yes.

INTERVIEWER: So what would an ideal lecture room look like, then?

SADOWAY: I think 10-250 is--

INTERVIEWER: What makes that better than 26-100?

SADOWAY: The pitch of the seats.

INTERVIEWER: It's steeper?

SADOWAY: Yes. 26-100 is-- first of all, there's a gulf between the front row and where the lecturer stands. And then the lecturer stands on a platform that's about two feet high. And so the lecturer is looking down on about the first seven or eight rows. And then the ascent is very gentle so the people are far, far back. And it's very broad and it's hard to make eye contact. When I lecture I'm constantly scanning because--

INTERVIEWER: 10-250 is deeper, I think.

SADOWAY: Yes

INTERVIEWER: And narrower.

SADOWAY: Right. And there's no gulf, so when I lecture I have a wireless mic and I can walk away from the board and to the students and even walk up the aisle, and at times look at the board. It's all part of trying to minimize the separation between the lecturer and the learner. And 26-100, even though it seats 550 students, I've lectured in there and I find it hard. 10-250 in its own way is intimate.

INTERVIEWER: You recently turned 60 and were honored by your colleagues and students and former students. Tell us about that. I don't think I've heard of many festivities like that.

SADOWAY: Well, this is something that comes from my research. I'm part of this community of people that study the properties of high temperature liquids that are a commonly referred to as molten salts. This community used to be strong in the United States but since the seventies 70s has been pretty much decimated owing to lack of research funding. I continue to soldier on and manage to figure out ways of getting myself funded here and there. But the dominant place for molten salt chemistry is Europe. And in Europe the they have a custom, or at least the molten salt community does, when somebody notable in the field turns 60 they have a symposium in the persons honor.

People come for several days and give papers, and there's usually a banquet and other festivities and so on. So about a year ago some people approached me and said, next year you're turning 60, why don't we have a symposium? And I said, no, no, no. I don't want to bother people. Well after some arm twisting, we agreed to have it and we decided we're going to have it at MIT. And it turned out to be a smashing success. There were about 100 people came. I had people from Europe, someone from Greece, from Germany, from the U. K., I had a contingent from China, from Japan. In fact, the vice president of Tokyo University came. He happens to be a materials scientist who had actually postdoc-ed in Toronto. At a different time from me, but we met on several occasions. I didn't know him very well but he came and he spoke at the banquet and so on. So we had two days of presentations, and we held it in 10-250. Symbolically appropriate. I even got a video greeting from Bill Gates.

INTERVIEWER: Have you met him in person?

SADOWAY: Yes, yes. He came to MIT in September of last year. I got a call from, actually an email from his secretary saying Bill's going to be in town. He'd like to see you, would you have time to meet with him? I said, I think I can make time. So he came to MIT and I met him on the steps in front of 77 and we walked down the hall to my office and we sat in my office for 90 minutes. We talked about 3.091, online learning, we talked about batteries, and so on and so forth. I saw him again when I was in Seattle for metals conference and we met again.

INTERVIEWER: Did any of the 3.091 course or the work you were doing tie in with either his Microsoft company or with his charity? Or was it just here's a guy who is broadly interested in the world, and stumbled across this and found it interesting?

SADOWAY: I think it's the second case. Somehow he was introduced to something I was doing in 3.091 and ended up watching all 35 lectures off of OpenCourseWare. It was surprising to me because there was an interview conducted by the Seattle Post Intelligence in June of 2009, during the last month that he was actively serving in the company. It was on the first paragraph of the interview, they asked him about next steps, what he's going to be doing about online learning, and so on. And so answers the first two parts about what his plans are and getting involved in some ventures and then out of nowhere he starts talking about, you can learn a lot online, I've been watching chemistry lectures and Don Sadoway at MIT and on, and on, and on. I was just astonished.

People started writing me, do you know Bill Gates was talking about you in this interview? So evidently it made some impact on him, and then we've continued to talk about energy, which he's come around to seeing as a critical problem that maybe isn't getting as much attention as, in his judgment, it ought to get.

INTERVIEWER: Besides your classes and research, you seem to be involved in a variety of other activities at MIT. One of them is the annual debate in Kresge auditorium over two Jewish holiday foods, latkes and hamentashen and which is better. You seem to be a great debater on both sides. What role does fun have at a serious place like the Institute? Do you think there's enough of it?

SADOWAY: Well first of all, I think fun has an important role. I think that we have to develop the whole person. Learning to laugh and learning how to make others laugh in a way that's not hurtful or offensive-- you know humor is very delicate. Just one little nuance and what was well intentioned as a good natured ribbing can be perceived as an insult. It's practiced. Being able to laugh at ourselves, I think it's all part of rounding out character.

So when the students at Hillel approached me for the first time four or five years ago, maybe it's a little bit longer, but certainly less than 10 years ago. They were having this first debated and they wanted me to participate in it, initially I balked because I didn't know what these foods were. But I consulted with the appropriate authorities and said, OK let's go. And had a ball. In fact, Walter Lewin was part of that first debate. It was absolutely hilarious. And everybody had a good time. It's grown over the years to a large number of people and I think that there's room for more humor. We do have the tradition here at MIT of hacking, and the hacks can bring a smile to one's face at a time of great stress. So I applaud the effort to introduce humor. And also, it's good for the students to see the professors having fun. I think they need to see the human side. So that's good.

INTERVIEWER: Were the students who approached you ones who had taken your class?

SADOWAY: Yes. Somebody said when they were making a list of who would be appropriate, they said Sadoway, get Sadoway. So I was honored.

INTERVIEWER: What's kept you at MIT all these years? It sounds like other people have been interested in your research and you're teaching--

SADOWAY: Oh, it's the students. It's the students. There are great students everywhere. What's different about MIT is that the average student here is at a very, very high level. It's a very special place. I would say it's the students.

INTERVIEWER: We're out of time. That's a wonderful note to end on. Thank you for an interesting and fun conversation.

SADOWAY: My pleasure.