INTERVIEWER: Today is December 14th, 2009. I am Karen Arenson. We are talking with Robert Langer. One of MIT's 14 Institute Professors, and the award-winning head of the Langer Laboratory, which works at the interface of biotechnology and materials science. A prolific inventor with some 750 issued and pending patents worldwide. His breakthrough discoveries have been critical and controlled drug delivery, tissue engineering in the battle against cancer. Some of his findings are also being used to make frizzy hair straight and to try to help Julie Andrews sing again using synthetic vocal chords. Professor Langer, thank you for talking with us today. Where do your ideas come from? Do you wake up every morning with ideas fighting to get out?

LANGER: Well, ideas come from all over the place. I've gotten ideas watching television. I've gotten ideas listening to music. I've gotten ideas listening to lectures. Sometimes I get a group of students and postdocs together because I have a specific idea, or a general idea, in mind and we just do brainstorming to come up with things. There's no single place, but I think they just kind of happen.

INTERVIEWER: Do they come in a steady stream or ebb and flow? And do you have as many now as you did when you started or more?

LANGER: I'd say they don't come in a steady stream. They do probably just come from different stimuli. And they don't just come from me. I mean, one of my things that's very important to me is to make sure that the laboratory that I run, which has a lot of students, undergraduate students, graduate students, and postdocs. I want them to feel like they can invent, that they can come up with ideas. So my hope is that whatever I do and the way I sort of work in the lab with the different people there gets people to feel free to have their own ideas. And sometimes really good ideas have come from my students as well.

INTERVIEWER: Among all your discoveries and patents do you have a favorite?

LANGER: People sometimes ask that question. Sometimes I give an answer that when they ask about my children, do I have a favorite? And so in a way, I love all of them. If I were to pick I suppose one of the discoveries we made-- actually, now over 30 years ago in controlled drug delivery, people used to think the conventional wisdom was that you could only deliver molecules that were very, very tiny through plastics. And we worked out a way to change the structure of plastics so that you could deliver molecules of any size. And I like to think that that had a profound effect on the field. And today in fact, many-- all kinds of molecules are put in these kinds of plastics and it's led to many new treatments for cancer, heart disease, and many other diseases. Also, it would lead to new bioassays for substances that could stop cancer blood vessels from growing and other things. So I suppose that that discovery, which we published in *Nature* and patented now back in 1976 was actually the original paper in *Nature.* You know, is certainly one that I feel proud of, but I like all of them.

INTERVIEWER: The one you were describing was in the Judah Folkman Lab?

LANGER: It was.

INTERVIEWER: Yeah, and do you remember how you dived in and how that came to you?

LANGER: Well, it was kind of empirical. I mean, what I sometimes say when I give lectures is I found over 200 ways to get it to not work. I experimented with all kinds of methods of making micro particles and polymer systems and most of them didn't work. Eventually I found a way to get it to work, but at the time I don't think we fully understood why it worked. It was a number of years later that we got more into the mechanisms of it and figured out why it worked. And it had to do with building in very intricate, porous pathways and tortuous pathways into the plastics. But basically it was just a lot of hard work and brainstorming and empiricism.

INTERVIEWER: Partly tenacity then.

LANGER: Yeah, I think so. I'm a very stubborn person and I probably don't give up very easily and it was very important to me to solve that because it also related not just to helping that problem, but working with Judah Folkman, one of my big goals and one of the things I was trying to do was to develop a bioassay for studying what we call angiogenesis inhibitors; substances that could stop blood vessel growth. And there were no assays then, so if we couldn't develop plastics that could deliver these molecules, which all these angiogenesis inhibitors were large molecules then we couldn't have solved that. And I'm glad we did. I mean, today the whole field of angiogenesis has become a very large and important area.

INTERVIEWER: At the front end did you think it was going to be possible and it was just a matter of figuring it out? Or did you go in saying, Hmm...I don't know?

LANGER: I'm an optimist, so I guess I believed that it would be possible. I mean, I think then and I think now that most things are possible. Sometimes you don't know how long it'll take to do them, but I'd like to think that most things are possible.

INTERVIEWER: Can you convey that optimism or teach it to students and postdocs? Is that something that you see as part of the education of a young scientist or engineer?

LANGER: I think that you can convey it in certain ways. I think, from a role model standpoint, you can convey it. And I think the people in the lab, in particular, they see what happens there and they see their colleagues or me doing things and solving problems and I also think you can do it as a mentor in terms of what I call positive reinforcement. You know, encouraging people. I don't think you can teach it, but I think you can help. And I think that in the different ways I mentioned, I think I try to help.

INTERVIEWER: What are some of the things you're working on now?

LANGER: Well, we're working on a number of things now. One big area is nanotechnology. We're working on creating nanoparticles that could specifically target anti-cancer drugs to tumors or other disease tissues. We're working on nanoparticles that can deliver new kinds of drugs like what are called say, RNA silencing molecules to cells. We're also doing a lot of work on what I'll call regenerative medicine. We're working on trying to come up with new strategies to create say-- well, really any tissue or organ by combining cells, including stem cells, with the right kind of plastic or polymer. And that could include, and does include everything from making new kinds of pancreases for diabetics to new spinal cords for people who are paralyzed and many other diseases as well.

INTERVIEWER: And how close are you to doing some of these things? What kind of progress and you--

LANGER: Well, what's happened if I look at the nanotechnology, we'll be starting a clinical trial in 2010 I believe to try to treat prostate cancer. So that'll be a very exciting time because it'll have moved the work that we started into the clinic and that's how you really begin to know just how well it'll work. Some of the others are in animal stages, and the testing has been promising. So I feel like we're making good progress, but you always want to move faster.

INTERVIEWER: How do you define what you want to go after? In other words, there are so many open questions and you have such certain skills and ideas.

LANGER: Well, I guess what I always try to think about is, what can we do with our skills and with our people that can make the biggest impact on the world? You know, and then you sort of look at all the ideas you have and ask that question. I mean, which of these things do you feel will make the biggest impact and you go after those.

INTERVIEWER: Are there lots of people going after the same question? One hears sometimes about races in science and do you tend to be affected by that phenomenon at all? Does it drive you or do you avoid things where lots of other people are racing?

LANGER: Well, I mean, a lot of times I've gone into areas where at least-- I think engineering sometimes races are a little bit different than biology. I think biology, like there have been races for DNA structure and things like that. And engineering I think, it's less so because you're not making a fundamental discovery of a structure. I mean, you're often trying to create or invent something. And I would say, at least in my case, a lot of the things that I've tried to invent or come up with haven't been things that sometimes the world or many other scientists thought were possible, so it wasn't like we had competition. You know, in fact a lot of times when I did some of these studies people were skeptical about them in the beginning and so I think that I haven't had that race in the same way. That being said, I mean, now I think there are over 200 of my own students or postdocs who are professors at other schools and they are working in these areas, and other people are working in them too. So I think that these areas have grown a lot since I started working on them now some 35 years ago. And to me, that's good. I want to see that happen because I want to see these fields grow and change and I want to see bioengineering become something that's really important to the world. And so if there is competition, if more people are working on these things, I mean, personally I think that's a good thing.

INTERVIEWER: Earlier this year *Nature* chronicled a day in your life. And it was a nonstop whirlwind from about 6:15 in the morning to nearly midnight. It included exercise and reviewing grant proposals and meeting with students and faculty, and teaching, and constant e-mailing, and even time with your family. Oh, and a frozen coffee chip yogurt with hot fudge sauce, was that a typical day?

LANGER: It's a typical day. I mean, there are other typical days too. I mean, I asked Helen Pearson, who was the writer I said, you know, another type of typical day is I'd be getting on an airplane and traveling somewhere and I think that's something else you do. But if I'm in Boston, which are probably more typical days than getting on airplanes. I think that month I had to travel-- I had five airplane trips, and I think two were overseas in that month. So that's one type of typical day. But sometimes getting on an airplane is another typical day. So there are different types of days. Sometimes I might be at a conference or something like that and so-- either in Boston or elsewhere, and that might be another kind of typical day. But if I'm at MIT that day was-- which I am most of the time, that's probably the most typical day.

INTERVIEWER: How do you find time to think on a day like that?

LANGER: Well, I think you get ideas all over the place. I mean, you get ideas and one of the things that you mentioned is I'm exercising, I'm reading, so actually I exercise a lot and whenever I exercise I have reading material or I have the TV on or music on, or all the above. Sometimes, like I say, ideas just come to you. Other times you're talking to students and postdocs and you're brainstorming with them. So I think when she visited me there were lots of different meetings. People from undergraduates, graduate students, postdocs, visitors, all types of people. Even that afternoon I think there was-- one of things I did is we have a UROP program and I think I had about 30 to 40 undergraduates for this pizza get together. And you know, they're asking all kinds of questions, which is great. So I think that ideas, you have lots of times where they just kind of happen.

INTERVIEWER: Do you have fun with your work?

LANGER: Oh, I love it. I really don't even think about it as work. You know, it's amazing that you can have a job like this where you can get to work with fascinating people, like invent things, do things to help people, travel every day if you want to. I mean, I don't want to. I mean, to wherever you want in the world. I mean, it's a fantastic-- to me, this is a fantastic opportunity, a fantastic job.

INTERVIEWER: Do you run into people who don't seem to have so much fun or does everybody in your field and again, is this something you can teach people if they don't seem to get it?

LANGER: I think there's a couple things that I guess I'd go over. I think one of the things that's hard for people in academics, one of the biggest things that's always sort of a big driver in terms of not having fun is probably raising money. You know, and so I think some people get discouraged because they have a hard time raising money and I think that's probably the biggest single negative to being a professor; at least at a lot of places. I suppose other things that could have effects on them feeling that way are pressure. I mean, pressure to publish, pressure to do different kinds of things. And then I suppose it's just really somebody's personal outlook, how they view the world. You know, are they less of an optimist or pessimist, is the glass half- full or is it half- empty? But yeah, there are a number of people who aren't probably as happy and there are other people who are probably very happy. I think you can try to teach some things if it has to do with grants. You know, I like to think that when somebody comes through our lab-- I have everybody help and pitch in and I try to encourage the postdocs for example, to write postdoctoral fellowships for a variety of reasons. First it's an honor, secondly it's some funding, but third, I think that gives them a taste of writing grants and I can try to help them with that. And actually, many of the people who leave our lab, their first couple of years when they're starting and even later, I've gone over their grants and try to review them and give them suggestions. So I want to see them do well. So yeah, I think that there are some things you can teach and help with.

INTERVIEWER: Let's talk about the path that brought you to MIT. Starting from where were you born, where'd you grow up, what were you like as a child?

LANGER: I grew up in Albany, New York. I don't think I was anything that unusual as a child. My dad and my grandfather played a lot of math games with me and I think that got me interested in math and I was pretty good in math as a child. And they also, when I was a little older, like 10 or 11, I got this Gilbert chemistry set and I think a Gilbert microscope set and I liked those kinds of things to play around with. And I think that that helped me get excited about science more than I might have otherwise. But I had a pretty normal childhood. I really grew up in a small house in Albany, New York and it was just fine. When I got done I really didn't have a very clear idea of what engineering was, but my guidance counselor and Dad said, if you're good in math and science that's what you should major in, and I had no idea what else to do. Anyhow, I went to Cornell as an undergraduate. Again, my first year some of the courses were hard for me. Chemistry was the thing I liked the best and was best at, so I had to decide after a year what I was going to major in, so I picked chemical engineering. And I studied that and when I got done being an undergraduate I again, really wasn't sure what I wanted to do so I figured I'd go to graduate school. And that took me-- I applied to a number of places and I came here at MIT as a graduate student.

INTERVIEWER: Were you in the engineering school at Cornell?

LANGER: I was.

INTERVIEWER: So you had gone in directly because people said you might like it or be good at it?

LANGER: Right. At Cornell you had to pick a different school, so I had picked engineering.

INTERVIEWER: Because the question of liking chemistry, but you didn't choose chemistry, you chose the chemical engineering.

LANGER: Right. So at Cornell they had a School of Arts and Sciences and they had a School of Engineering, which was actually about 10 schools. But I had chosen the engineering school to begin with, so it wasn't like I could have been a chem major. You know, it wasn't part of the engineering school.

INTERVIEWER: Did you have people in your family who were in science or engineering? I mean, even the fact that they were playing-- that your father and grandfather were playing math games with you suggests that maybe they were in fields that were related?

LANGER: They weren't. I mean, they were very smart people, but my dad ran a liquor store for a good part of his life. My grandfather worked in a-- or his father worked in a brush factory. I think my mom's dad worked in a clothes store. But I think they were very intelligent people. I mean, my dad would do the *New York Times'* crossword puzzle all the time and do it pretty quickly. I'm sure I couldn't do it. There's a different time. I mean, my dad actually went to Harvard for a master's degree in English, but he got out in the Great Depression and I think he said there were two jobs he could have taken. One was in North Dakota and the other probably someplace not that different. So he didn't do that. And ultimately he went into the war and came out and married my mom. But I think that it was a very different time in history compared to where we live in today.

INTERVIEWER: But did he play word games with you too? It's interesting that he was playing math games with you even though he had been an English person at Harvard.

LANGER: He didn't play word games with me, no. At least not that I remember. I remember the math, but they were very good-- both he and my grandfather at playing math games with me.

INTERVIEWER: Did you have a favorite math game?

LANGER: I think I would just like-- I think when I was little I could count higher than most people and I could add up things. So sometimes it was just how high could you add something up, but I could do that at a pretty young age.

INTERVIEWER: You mentioned that you weren't sure what you wanted to do, so you figured you'd keep going in graduate school and applied to a number, why MIT?

LANGER: Well, MIT-- MIT as a graduate school, I think there were a couple things. One, I think, it probably was the best or at least close to the best. But secondly, I remember when I looked at the ChemE program at MIT in 1970 when I came here, one of the things that appealed to me since I didn't know what I wanted to do-- MIT's Chemical Engineering Program at the time seemed very diverse to me. It had applied chemistry, it had polymer chemistry, it had bioengineering a little bit. You know, so it seemed more diverse to me than most of the other departments that I was looking at and that had appealed to me since I wasn't really clear on what I wanted to do.

INTERVIEWER: What were your first reactions when you got to MIT? I mean, you were in a very different place from Ithaca I guess.

LANGER: Yeah, well I guess a couple things. One, Boston was a lot more expensive, I remember that because I remember I think, I paid $60 a month for my apartment at Cornell. And I had a pretty nice apartment. And then when I came to MIT I think I was getting a stipend of $240 a month and I thought I'd get this mansion. And I remember coming up with one of my friend's from Cornell because he was also going to be at MIT and we looked at apartments and we couldn't believe how expensive it was. So we didn't get any mansion.

But secondly, it was hard. It was hard as a first year graduate student. So those were a couple of the early impressions I had.

INTERVIEWER: You actually did some things besides chemical engineering. You were active in community service then. Some graduate students seem to make their whole life their graduate work, but that wasn't the way you went about it.

LANGER: No. Of course, this was the late 60s and early 70s. And I think a lot of people were interested in maybe doing-- or at least some people were interested in doing things broader than just their schoolwork at MIT. For me, when I was an undergraduate at Cornell I was a teaching assistant my senior year and I loved that. So when I came to MIT I was trying to figure out ways also that I could help people and maybe use some of my skills, and I really enjoyed the teaching very much, so I helped do tutoring both in Roxbury and there was a place called the Education Warehouse in Cambridge. I got involved with MIT's urban action and got different teaching things through there. Then I got involved with helping start a school called the Group School in Cambridge. And I spent several years doing that. In fact, I headed the math and science department. And I even got MIT involved in various ways, both by having a variety of programs here where students from school would work in the labs and where we developed new chemistry curricula and things like that. I spent an awful lot of time doing that, but I loved it.

INTERVIEWER: And your teachers, your professors didn't discourage you?

LANGER: Well, that's an interesting question. I'm not sure for awhile that my professors knew how much time I was spending on that. I think that they might have, had they really known how much time I was spending. But I also spent a good deal of time-- I was doing two things. I'd either work in the lab or I'd be doing the tutoring or being at the school. And when I worked in the lab it was often late at night and so my particular professor was around late at night, so he saw me working late at night, and so I guess I was able to do both.

INTERVIEWER: You ran very long days then too it sounds like.

LANGER: I guess I've always ran very long days. I guess that's my life, but I like it that way.

INTERVIEWER: Do you still do anything along those lines? Are you involved in high school or pre-college education?

LANGER: I do to a certain extent. I give a lot of lectures-- I mean, for a professor, I guess, I give quite a few lectures at high schools. So I have done that. And we have had high school students work in the lab, so I certainly do some. And I really feel it's important. I mean, I've even lectured in grammar schools. I feel it's important to try to communicate that science can really be a good thing. And so yeah, I do.

INTERVIEWER: Do you have thoughts-- there are lots of concerns that not enough American students go into math and science and engineering. Do you think there's anything we can do about it? If you could wave a wand what would you do?

LANGER: Well, I think there's probably a lot we can do or that the nation could do about it. I guess if I could wave a wand I would think of a couple things. One, I think it would be very important for the government to put more funding into high school and grammar school education in science. I think that that would be really valuable and I think there are specific things that could be done. I also think the media and maybe there could be some ways to contribute funding to that, but I think the media glorifies actors and sports heroes and singers. And they don't glorify science very much. So I think the message that young children often get is that science isn't very important and particularly, they're watching TV or on the computer, whatever. So I think those two areas, grammar school and high school education on the one hand and media on the other hand are probably two of the big forces that could really help.

INTERVIEWER: You said if there were more federal money there are certain things that one could do. Such as? LANGER: Well, I think you could put more money into developing innovative curricula. You could probably, I mean again, I think it's almost unlimited probably, what you could do. I mean, you might want to put together some panels to really look at this carefully and come up with a list of priorities, but I think public school teachers could get higher salaries. I think that you could come up with new innovative laboratory things. I mean, maybe you could even create some opportunities for media to do a better job on science. You know, maybe you could put more money into science museums or other things like that. I think one might make more interesting kinds of science games. I think it's almost unlimited the kinds of things that you could do better television shows that make science exciting in different ways. You know, a lot of these would be challenging, but I'm sure they could all be done. But a lot of times people-- if there's funding you can do all kinds of things. I suppose other things could be funding to help universities interact with high schools or grammar schools. To me, you could go on and on with the kinds of things that could be done that I think would help education for young people.

INTERVIEWER: Some of the challenge would seem to be getting enough role models who are interested in these areas. If not at home, in other words, if you don't grow up in a house where you play math games as families as MIT kids do, I think. And you get to a classroom where the teacher seems to recoil from math or science instead of getting really excited about it, how do you begin to find the people who will convey that excitement and move them into the schools?

LANGER: Well, I completely agree with you and that's why one of the things that I was saying is again, if you put more funding into it then you could probably give fellowships for people to study math. You know, you could just lower the bar to get more people into science or math education and so on the one hand you could get more people who would be more role models. On the other hand, you could have curriculum development done that would make it more exciting for those people and others and you could try to create curricula that would be exciting for people at any age. And I think that those kinds of things would be really valuable. I know when I taught at the Group School and I was the first math teacher there, and I remember that was a very liberal school so their policy was that you only had to take math if you wanted to, not because you had to. And I think the first year I came, five people out of 37 took it. But I spent a lot of time trying to think how to make it interesting and came up with different kinds of math games myself. So the second year 45 out of 50 people took it. So I think that there are things that can certainly be done, but there's so little funding and it's so low a priority unfortunately in the nation's scales and on the media scale, so I think that unfortunately, these things don't happen.

INTERVIEWER: When you first came to MIT in chemical engineering you said that it was a more diverse department than many ChemE departments, and that there was even a little bit of bio, did you come in with any kind of biology training or did you get it here? Did you ever study biology?

LANGER: I hadn't studied biology other than 10th grade and my bachelor's thesis at Cornell, I actually did something with red blood cells. But I mean, I wouldn't call that much of a training. I just learned a little bit. So it was very limited.

INTERVIEWER: So for your undergraduate thesis on red blood cells, what did you do with red blood cells and why'd you choose that?

LANGER: Well, I was interested in bio things, even then. That was in 1970, spring of 1970. So one of the professors of Cornell, Bob Finn, that was his area, was blood cells and red blood cell damage and I think I looked at factors that caused red blood cells to be damaged. And maybe ways that we could protect them. So I mean it was kind of just a small bachelor's thesis, but that was the first thing that I'd done.

INTERVIEWER: And did you choose him because it looked like an area you were interested in or you chose him for some other reason and this happened to be the thing he was working on?

LANGER: I chose him for two reasons. One, I liked him. I had him in a class. He was a nice guy and we got along well. And two, because it was an area I was interested in.

INTERVIEWER: And even for that thesis, did you have to start reading then about blood cells and biology and so forth and teaching yourself?

LANGER: I did. I started reading then a little bit about blood cells and biology and teaching myself. I don't think I was any expert by any means, but I did start to learn a little bit.

INTERVIEWER: And by the end of that thesis, did you say, hmm... here is an area-- I mean, you said you came into graduate work not knowing, but did it begin to be something that was forming in your mind, do you think?

LANGER: Not really. I mean, I think that I did it and I think that was a taste of research. It was okay. You know, it wasn't that I had done anything particularly important. So I really didn't know at that time.

INTERVIEWER: And your first year of graduate work, did you take a bunch of courses all over the place or how did you structure it?

LANGER: Well, when you came to MIT and when I came in 1970 mostly there were courses that you're supposed to take so that you'd pass or not pass the doctoral qualifying exam. I mean, there were some required courses, so I took those. Thermodynamics, heat and mass transfer, industrial chemistry, and there were a couple of others. I think I took catalysis and maybe one other. And really, the sense that you got from your advisors and everybody else was that you should take these courses, do as well as you could, and hopefully pass the doctoral qualifying exam. So that's what I did in my first term.

INTERVIEWER: And were those course that have turned out to be really useful to you or are they courses that would have been useful to you if you had gone into the oil industry or something?

LANGER: Well, it's interesting question. On the one hand I mean, it's not like I use, or at least I don't think I use those tools today. But one of the things that I've always thought was good about chemical engineering was that it's like a really broad background and it teaches you how to think. And it teaches you how to think broadly. And maybe get you into this kind of problem-solving orientation. So I guess the way I've always thought about it, correctly or incorrectly, is that learning all those things the way I did gave me a good general background, even though the specifics I probably don't use at all.

INTERVIEWER: What did you do after that? How did you begin to shape your--

LANGER: Well, at the end of my-- so after you pass the doctoral qualifying exams then the next thing is you pick a thesis adviser and I looked around at what different people were doing. There weren't really that many things that were of interest to me. And I think it came down to two different professors at MIT that I was talking to and I ended up choosing one of those. It was Ed Merrill and Clark Colton and I ended up-- Ed was doing things in polymers and a little in bio and Clark was doing things in the bio area. I think he was the only one in the department that was other than, like I said, doing a little bit. And I ended up choosing him.

INTERVIEWER: And what was your thesis area?

LANGER: My thesis that I did for my PhD was called enzymatic regeneration of ATP, adenosine triphosphate. And the goal was part of a larger project that MIT was involved in to look at enzymes for synthesizing things. And ATP was the energy source, so my goal was to see if I could try to create a process that might someday be industrialized that could do that.

INTERVIEWER: So it sounds like by then you were beginning to think, hmm... this bio stuff is interesting. Did you go take any classes in it or do more reading?

LANGER: The bio stuff appealed to me. I didn't take classes in it. I mean, they were hard to fit in my first year and then after that I read stuff and I guess I went to biochemistry. I sort of audited biochemistry 705. But I didn't really take a specific course.

INTERVIEWER: Looking back could you have done more of that, or it just didn't matter? I mean, because you accrued it as you needed it.

LANGER: I could have. I probably could have. I don't know if it would have mattered or not. You know, it's an interesting question. I think when I end up looking at the way my career's going and the different things I've done I don't know if it would have mattered. Yeah, it's hard to say. I've never been a great classroom learner. I mean, even with the classes I would end up kind of teaching myself more than-- like I've never been great at listening to lectures. I just daydream and things like that. So I'm not sure that classes--

INTERVIEWER: Your mind is working.

LANGER: Well, I don't know if it's-- I mean, some people could say that my mind's just working. Others could say that I have Attention Deficit Disorder, and maybe both are true. Which is fine. I mean, I think that it was just not my learning style.

INTERVIEWER: Did not having a lot of background in biology-- was that a disadvantage or maybe even an advantage to you?

LANGER: Well, I think that cuts both ways. I think when I started doing my postdoctoral work in particular, which was in a biological area, not having it certainly made me struggle more. But on the other hand, I think I also probably did take approaches that were not bound by conventional wisdom because I didn't know anything.

INTERVIEWER: Once you got your doctorate, what did you do next?

LANGER: So when I got my doctorate the next big challenge for me was to figure out what I was going to do with my life. And that was a challenge, so I spent a lot of time my last year of graduate school interviewing in jobs. And I had a lot of interviews. Most of my classmates at that time, '73-'74 were going into the petrochemical industry. They had all kinds of job offers and that's mostly what I did too. I ended up interviewing at Exxon four different times because they had places all over the country at Shell and many other places, and that's probably what I thought I would do because that's what most other people did. But I didn't like it that much. I always think about this one interview I had at Exxon in Baton Rouge, Louisiana and one of the engineers there told me if I could just increase the yield of some of these petrochemicals by 0.01 percent, he said, that would be great. He said, that would be worth billions. And I just remember flying back to Boston that night thinking I don't want to do that. You know, I wasn't excited by it. I didn't know exactly what I did want to do, but I could see that the conventional path of just going into industry and the petrochemical industry was something that at least wasn't that exciting to me.

So then I started thinking about other things and in particular, since I'd spent so much time at the Group School and developed new chemistry curricula and things like that I was very interested as I started thinking about it more and more in education. One day I saw an ad in one of the journals for an assistant professor of chemistry, actually at City College of New York. Developing chemistry curricula and I thought that was great. And so I wrote them a letter, but then they didn't respond to me, but I liked the idea so I kept looking for positions like that. I probably found about 30 positions like that. Most of them not at particularly good schools, but none of them wrote me back. You know, I wasn't in this box, even though I'd gone to MIT, I wasn't in this chemistry education box. So I guess people don't write you back. So that didn't work either.

So then another thought I had, I was interested in using my education to help people. And so I started thinking about medicine. And so I wrote to a lot of hospitals and medical schools, who didn't write back either. Another way I always tell the story, which is true is one of the postdocs in the laboratory I was in said to me, said, Bob there's this surgeon at Children's Hospital named Judah Folkman. He said, sometimes he hires unusual people. I wrote him and he was kind enough to call me up and I went over there and he had some projects that were just to me, incredibly exciting. And so I ended up working there.

LANGER: Did he have other chemical engineers working for him ever before or was this a real-- were you very different for his lab?

LANGER: I was very different from his lab. I think he had some exposure to chemical engineers and he was a broad thinker, but nobody in his lab in 1974 was an engineer. I mean, they're all biologists or surgeons or microscopists, or biochemists. I mean, there was nobody even close to an engineer.

INTERVIEWER: And looking back do you think he had any kind of sense that an engineering set of skills would be useful for what he was trying to accomplish? I mean, it doesn't sound like he had thought, oh, I need an engineer and he was out looking for one. Nonetheless do you think there was some light that went on or he just took to you?

LANGER: Well, I think what he said to me was that-- which corresponds to something you asked earlier-- is that he said, a lot of people have been trying to-- and what he was interested in was could you find a substance that could stop blood vessels from growing in the body? And he said, a lot of people have looked at this before that had more conventional approaches, like biochemists. He said, they never succeeded so we wanted to find somebody that maybe was he thought reasonably intelligent, but would take a fresh look at it.

INTERVIEWER: And the first day you showed up in the lab, where did you even you know how to start or how did you go about it?

LANGER: It was hard. I would try to do reading and then I would talk to some of the people in the lab there. Then I would talk to him. I would do more reading. I'd get involved in some experiments. You know, I'd kind of go back and forth between talking and reading and experiments and keep going that way.

INTERVIEWER: Did you give yourself a time frame or did he give you a time frame?

LANGER: I don't think you have a specific time frame. I mean, I suppose you want to try to accomplish something in a couple of years, but I don't think there was a deadline. You wanted to solve the problem as soon as you could, but it was a hard problem.

INTERVIEWER: Did you have to invent new tools to do that at that time?

LANGER: I did. I mean the biggest new tool was trying to come up with these polymers that could deliver large molecules slowly over a long time and not cause damage to the body and that would lead to another tool, which was these bioassays that one could use to study angiogenesis stimulation or angiogenesis inhibition. So those tools were critical to solving a problem. They're still widely used today.

INTERVIEWER: Was there some point when you begin to think, I'm on the right path?

LANGER: Yeah, well with the polymers I developed these assays, which you could put things in these polymers, little pellets and I had these gels. And the idea-- there were different substances that I would put in the polymer pellets and the gels would change color if they were coming out. So I would put them on the gels every day. Most of the time, by the second day there was nothing coming out. I mean, almost always. But I remember with one particular design they'd keep coming out day after day, even for 100 days. So as you could keep seeing the color changes then you knew that you were on the right track.

INTERVIEWER: Did you put your head into his office and say, oh my goodness, this is beginning to work or something?

LANGER: Well, I think I would show-- I'd take him and I'd show him the gels and that was really exciting. It was great to see them change color. I mean, in one case the gel would sort of clear out and become transparent and another case it would turn a particular color. Yeah, I loved doing that.

INTERVIEWER: As you worked did you ever go back and talk to some of your former professors? Were they useful in consulting? Or did you turn to anyone else in the field that you knew or was this pretty much a solitary project?

LANGER: Well, I talked to Dr. Folkman a lot. I did talk to other people in the lab that were surgical fellows I was working with. It was a biochemist that I was doing some work with. I don't think the chemical engineering professors-- I didn't turn back to them I guess in this case. Most of what I was doing was in such a different area and so few of them were working in that area.

INTERVIEWER: At some point did you start thinking of going into academia? You didn't stay full-time in that lab forever. How long were you there and what did you do next and why?

LANGER: I was there three years. Most of the time of course, nobody did, in chemical engineering, at least a postdoc, which in essence was what I was doing then. I actually probably would have been happy, at least the way I looked at it, staying there a long time. I really enjoyed what I was doing. But I don't know, some of my friends kept saying in the lab, David Kessler for example, who'd later become head of the FDA, he said, Bob, you shouldn't be a postdoc forever. He said, you should become a professor. And so I started applying to schools.

INTERVIEWER: Including MIT?

LANGER: I did. Not right away. I actually applied to a lot of schools in chemical engineering. I knew MIT wasn't hiring in chemical engineering. At that time they weren't hiring anybody inside that had graduated from the department. They did that for number of years. But I applied to a lot of other schools in chemical engineering and they didn't want to hire me. I mean, they were intrigued. They offered me job interviews, but I think when I went to those schools they were saying, well the kinds of ideas that I was talking about, like angiogenesis and drug delivery, and I had some ideas on enzymes-- I mean, they said, "Well these aren't chemical engineering." They don't see that as chemical engineering. It's interesting to see how chemical engineering is today on the other hand. I mean it's interesting because what I was doing ended up becoming chemical engineering of the future, but it wasn't chemical engineering at that time as they saw it. So at any rate, I didn't get any of those positions. Dr. Folkman then later talked to Nevin Scrimshaw who was head of the nutrition and food science department at MIT. Because Dr. Folkman talked very positively about me, I guess, Nevin Scrimshaw offered me a position in what was then the nutrition and food science department.

INTERVIEWER: Course 20?

LANGER: Course 20. And so I came here.

INTERVIEWER: In that department, not in ChemE?

LANGER: That's right. I came here in 1977 as a visiting assistant professor. I still actually maintained the lab at Children's Hospital, but I came as a visiting assistant professor in 1977, as a regular assistant professor in 1978 in nutrition and food science and later on that would become the Department of Applied Biological Sciences.

INTERVIEWER: How well did that work? I mean, how was the fit once you got here in that capacity?

LANGER: Well, there were positives and negatives. I guess I felt from the standpoint of the students it was very positive. The students were I think, very excited about what I was doing. I had a lot of students who wanted to work in the lab.

INTERVIEWER: Mostly grad students you're talking of?

LANGER: Yes, graduate students and also undergraduate students. I got some postdocs too. So in that sense the fit was good, but the faculty in those days-- the nutrition and food science department when I came to it sort of had five distinct areas. And what I was doing really didn't fit in any of them. So I think it's fair to say they weren't real positive about me. I recall there was a time a couple of years after I started where several of the senior professors told me that I had no future in the department and that I probably should leave.

INTERVIEWER: And your reaction was-- or how'd you--

LANGER: Well, my first couple years-- I should add to that, it wasn't only that they told me to leave. It wasn't like I was doing that well in grants either. I had my first nine grants turned down. I also had a lot of people feeling that the science-- since what I was proposing and what we were doing sort of went against a lot of the conventional wisdom-- I had a lot of people, I think, who were skeptical of the science that I was doing at the time. I mean, not necessarily at MIT, but outside MIT. So my first three years from the standpoint of my future probably weren't that good in that sense. I mean, that's probably putting it mildly.

INTERVIEWER: Could you have fit in some hospital somewhere and did you ever think of whether you should go get a medical degree or go work in a hospital research setting?

LANGER: I thought about it, but I also felt that, at least from what I could see, that the people who were driving things in medicine were medical doctors. I don't say that I'd necessarily be a second class citizen, but I think that I could see some value in having the background that I had and being in a more scientifically or engineering based department. I also, I suppose, to a certain extent was doing that. In other words, I still for many years-- I mean, I still have it today-- I had an appointment at Boston Children's Hospital. I had a lab there too. So in a way, I really was having both. I did have a medical appointment. I mean, in terms of doing research and I had this more academic appointment at MIT. So in a way, I was still doing both. And I would actually drive back and forth quite a bit.

INTERVIEWER: How did you get out of this crunch? What finally made it begin to fall into place?

LANGER: I think what happens is after a period of time and certainly this happened for me, people on the outside were positive about-- they felt I was doing important things. You know, the NIH decided that the grants were important. I got really good reviews. People in industry, like I think somebody-- they write letters to people. I think they wrote to Roy Vagelos who was president of Merck at the time and he said that I was doing really good things. So a lot of people on the outside started to say that this work was really important. That they'd like to have me work for Merck or work for them. And so I think that people wrote very strong letters or they gave very good feedback. Again, I was not directly involved in this, but this was kind of what I heard. People felt that the things that I was proposing and doing, they were important and they might change the way pharmaceutical science was done.

INTERVIEWER: So you were still in nutrition and food science at that point? Headed for maybe not getting tenure or they did give you tenure after all? Were you moved?

LANGER: No, I was headed for-- according to some of them, not even getting reappointed. But I did get reappointed. I did get promoted. I actually got tenure even early. But the first couple of years were tough. And then it just totally turned around because I think the message from the outside world, in many ways: grant support on peer reviewed grants, of papers, and I would publish and this was very unusual for an engineer in journals like *Science and Nature.* You know, very, very high impact journals. And students really liked what I was doing. So I think in the end all those things turned it around and so everything changed.

INTERVIEWER: And so suddenly the department, instead of having five traditional pathways had a sixth one, yours?

LANGER: Well, I don't know if they looked at it quite that way. I don't know that they looked at it quite that way. And I think the department kept changing in different ways. But they just hadn't made an addition and later on they'd have Alex Klibanov, who was doing some different things. And so I think the department had some new leadership by Gerry Wogan at that time and it just kind of took a different attitude. They were getting more interested in I guess what I'd call biotechnology and I think, in a broad sense what I was doing, and later what Alex was doing would fit into biotechnology.

INTERVIEWER: At some point though you moved into Course 10, the chemical engineering, when did that happen and how?

LANGER: That happened in 1988. And what happened in 1988 was that MIT-- so the nutrition and food science department in 1985 changed its name to the Department of Applied Biological Sciences. And in 1988 MIT decided that they didn't want the department anymore, so they sort of reorganized everything and different people in that department went to other departments, and I went into chemical engineering.

INTERVIEWER: So that would've been in the School of Science as opposed to the School of Engineering?

LANGER: That's correct.

INTERVIEWER: And you really had an engineering background and an engineering approach to work even though you were working on scientific problems, I guess. What was that like? Did it matter?

LANGER: I think it was maybe complex in some ways for people in the school of science to judge an engineer. But on the other hand, what they would do is they would write letters to people and I think my papers were in journals that even if I was an engineer-- like I said, I did have papers in *Science and Nature* that they could judge were high impact papers. I had quite a bit of peer- reviewed NIH grant support by that time and NSF grant support. So I think there's certain kinds of criteria that people could use and I think probably did use in my case.

INTERVIEWER: And then you moved into the engineering school because your department folded and it seemed like the best fit.

LANGER: That's right, I was a chemical engineer and they came over and talked to me in chemical engineering and asked if I would join that department. I mean, probably there were other places I could have gone. But yeah, I think what you said is right, it's probably the best fit.

INTERVIEWER: And in terms of your lab work, were you doing it on campus at that point or still doing it over at the hospital?

LANGER: Most of it was on campus at that point. I probably did a little bit at the hospital. I did do some at the hospital, even by 1988, but I did most of it here at MIT.

INTERVIEWER: And students were beginning to be very interested in these areas and you were one of the few people on campus doing work in this field?

LANGER: That's right. I mean, certainly in 1988 there weren't a lot of people doing work in this area; very, very few. And I had an enormous number of students interested. In fact, I think when I started doing this, when I first joined the ChemE department in 1988 I think something like 13 or 14 people out of 25 put my lab down as their first choice for a doctoral thesis. Then, of course, they ended up having to change some rules after that. I didn't take all those people, but it was very popular.

INTERVIEWER: And did that fuel any kind of recognition in the department or the school or at the university that maybe they needed to do more of this? Or that it was a hot area or growing area of interest?

LANGER: Yeah, well certainly over time it would. I don't know if it was because of that or because of me or what I did was just a part of it. But I think overtime a whole range of things, student interest, impact, NIH funding probably did allow MIT to see that these things were potentially important.

INTERVIEWER: Did any other universities have more of a biotechnology approach or centers of activity? By this time we were talking about, I guess, the late 80s.

LANGER: I would say no. There were some departments of biomedical engineering certainly and MIT did not have one, so there were few departments of biomedical engineering. And chemical engineering, I would say probably not. You know, I think that usually they had like one-- every school sort of had their one professor, maybe two, but usually one.

INTERVIEWER: Would it have been helpful to you had there been a larger critical mass of these people in a bioengineering department at that time? Do you think it didn't really matter?

LANGER: Might have been a little helpful just to have had mentors and stuff like that, but in the end I gained from collaborating with people who were very different for me. I don't know. It's always hard to know. I didn't have those controls, so I don't know.

INTERVIEWER: When MIT approved the new degree in biological engineering it was the first new course of study I think, that they had approved in something like 39 years. How much difference has that made? Has is made any difference to you and what about students?

LANGER: I don't know if it's made that much difference to me because I pull in people from probably about 10 different disciplines, both at the graduate level and postdoctoral level and undergraduate level. I think from a student standpoint it makes a difference. I may not be the best person to judge that, but I think it makes a difference. I think a number of students take that option and are excited by it.

INTERVIEWER: You mentioned that you were beginning to get some outside recognition earlier on at places like Merck and other pharmaceutical companies, did you ever consider going to work for a company like that? For Merck or for another company in that business?

LANGER: Well, I mean I did a little bit. They offered me positions and they offered me good positions. So did some other universities and so I thought about it from time to time. The offers continue to this day, both at companies and other universities. And I have to say, I've thought about it a little bit from time to time, but I've never left.

INTERVIEWER: What holds you here?

LANGER: Well, I mean, I still think MIT is the best place and I think that-- what does that mean? It means I've been able to just have exceptional students and exceptional colleagues. There was a time when I would get incredibly good offers from other universities and I was not a full professor here and they would offer me sometimes much higher salaries and much greater packages and stuff like that. And they were some pretty good universities, but I guess I felt that would come in time here too, you know, and it has. Well, maybe not all the things they would've offered, but a lot of things have. I think also it goes back to me-- it goes back to the point that you asked me earlier about how I pick ideas. How can I have the greatest impact? And I really feel I can probably have the greatest impact here. You know, some of the positions at other schools are leadership positions, being head of institutes or deans or whatever. I mean I probably could do them and I've had people offer me things like that here too, but I think doing what I do I probably has the greatest impact.

INTERVIEWER: There's some people who delight in starting new things but take less satisfaction in running them on a day- to-day basis. You seem to have done both, do you get equal satisfaction from both?

LANGER: Well, I get a lot of satisfaction from both. I probably like starting things more in a way, but I also realize that if I'm going to make an impact I have to finish them or at least I have to follow them through to the point where they'll be strong enough to succeed on their own.

INTERVIEWER: What was involved in setting up your own lab here? When did you actually do that and how did it develop?

LANGER: Well, it really would evolve over time. You know, when I first started I didn't have very much lab space at all. I was doing things at Children's Hospital, but I was running the teaching lab so the nine months a year that I wasn't using the teaching lab I'd have more lab space here and I'd use it. Then I was actually the first occupant of the Whitaker health sciences building in 1982. That was my first real lab space. I didn't have very much, but we kept on getting a little bit more, a little bit more and that's still where we are today, though we'll be moving to the Koch Institute building as soon as that opens. But basically the things it involved were equipping it and equipping it more, but mostly it's all about people. I had great students at different levels and then really good postdocs so that's how I would do it.

INTERVIEWER: How many applicants do you get to work in your lab? There must be--

LANGER: Now? Thousands every year. But some of that has to do with publicity we've gotten in different journals like *Science* -- both *Science,* I forget what the number was exactly, and then*Science* in 1999 had a cover story about what it's like to be a postdoc. And they highlighted our lab in particular. In fact, I think they had nine of our postdocs on the cover. Had really a very positive article about what it was like to be a postdoc in our lab and then the number increased quite a bit. And then I think this year, as you mentioned, *Nature* wrote an article about what it was like to--

INTERVIEWER: To be Bob Langer.

LANGER: To be Bob Langer, but to be in our lab too and the number increased again.

INTERVIEWER: Like being John Malkovich.

LANGER: Yeah, right. Right. So we get an awful lot of people. I mean, thousands.

INTERVIEWER: How do you sort through them and what do you look for?

LANGER: I guess there's a lot of things. Sometimes it happens that particular people I know, the professors I might know might write me or call me or the student works for them and that's one thing. Then I have a real easy path to find out how good they are. I also look at the quality of schools, the quality of the publications. If somebody sends a letter saying this is by far the best person they've ever had, I look at that. I also have some people in my group help me. So I do all those things.

INTERVIEWER: But is there something about trying to judge the quality of their creativity or the quality of that plus their stubbornness? In other words, do you sort of look for yourself in these people and do your pipeline professors, your network understand that or are they good at judging those things too?

LANGER: Nobody's perfect at judging those things, including me. But I think you can get some sense from what their advisors say and what the people who've known them say. And I think that that's very helpful.

INTERVIEWER: Does your having struggled a little in sort of finding the right path affect how you choose people or what you look for? Was the initial problem maybe just that the path you wanted didn't exist yet and that was why you were having trouble getting onto it?

LANGER: I think some of both. I think the fact that the path that I wanted didn't exist was important. And I do, if somebody has a really outstanding background-- I'll just make this up, but let's say somebody came to us with a physics or electrical engineering background and they were just a superstar. You know, I would be interested in that person even if they didn't have exactly the right background for the lab. But generally people will apply to the lab who have backgrounds that seem to fit with the things that we've published on.

INTERVIEWER: And what are the constraints? I mean, you have about 100 people in your lab, I think. I mean, could you have 150 tomorrow if you wanted or is it a question of how much grant money you've got at the time or what projects-- in other words, what determines how fast you grow and where you put people and so forth?

LANGER: Well, there's two things probably-- three things: space, money, and time. I'd say space is probably the single biggest limitation at this minute. I mean, that may change, but space is probably the biggest limitation. I think you also don't grow really fast. In other words, our lab is very, very large, but it didn't grow like in an instant. When you have a number of people they can help other people and so I wouldn't want to grow from 100 to 150 in an instant. I'm pretty happy with where we are right now, but a lot of it depends on the problems you're trying to solve, the grants you get. And then we've sort of done a slow growth, but we've done it over many years.

INTERVIEWER: Are there disadvantages to being so large or are you not at that point yet?

LANGER: Well, I think there are pluses and minuses. I personally believe the pluses outweigh the minuses, particularly for the problems we're trying to do, which are very interdisciplinary and sometimes take the ideas all the way from an idea to the point where it'll be in the clinic or close to it. But sure, I mean, if there's a lot of people I probably can't spend as much time with any one individual now as I did say, 25, 30 years ago.

INTERVIEWER: What makes a successful lab? LANGER: I think the people feeling hap-- I think a variety of things. I think the people feeling happy, feeling fulfilled, making an impact. I think those kinds of things.

INTERVIEWER: Do you have many undergraduates there?

LANGER: We do. My understanding from the UROP office is we have the largest number of UROPs in MIT. So yeah, I'd say we probably do.

INTERVIEWER: That's the Undergraduate Research Opportunities Program?

LANGER: Right. When they had their 40th anniversary they wanted me to speak and that was one of the comments they made. They said, "I have to since we've had more UROPs than anybody else in the history of MIT."

INTERVIEWER: I mean, is this like a handful each semester?

LANGER: Oh, we probably have 30, 40 UROPs. Maybe 30 to 50.

INTERVIEWER: And do some of them then come back semester after semester?

LANGER: Most of them do. They've really enjoyed it and so we have a lot of return people. I've had people start as a freshman and go all the way through senior year.

INTERVIEWER: Have you seen much change in students at MIT since you started teaching and running a lab, or not?

LANGER: There's some change, but I think in a fundamental way, not really. Well, I shouldn't say that. I think there are certainly many more women now than there were when I started. I was going to say I think there's more of a social conscience, but I'm not sure. I'd have to think about that more. But there are some changes.

INTERVIEWER: And there's been so much attention in recent years, particularly after Larry Summers made his comment about women in science, do you see different styles among the women and the men overall, or not really?

LANGER: Well, I mean all people are different: women and men. You know, men and men are different and women and women are different. I'm trying to think whether I'd say I see different styles. I guess I feel it's almost too much of a generalization, but I do think that young women-- it's really good and nice that there are women professors because I think it's nice, as we talked about before to have a good role models and I think that that's a very helpful thing for young women to see.

INTERVIEWER: Do you have any advice for students or for researchers about how to make a students experience in the labs successful, useful, interesting?

LANGER: I think you want to pick really important projects. And to amplify that a little bit, I think it's good, I think it's okay to take risks. I think that that's good to try to shoot for high impact projects. And so I think that's really important. Sometimes people don't because they're afraid about tenure or grants. They won't necessarily do that, so I think that that's one thing that I do think is worthwhile doing. I think that being said, you also want to think what'll make good project for students and so there ought to be, even if it's high risk, stopping off points so that they'll get some papers and they'll be able to accomplish some things.

INTERVIEWER: Were you a risk-taker as a child?

LANGER: I don't know if I was. But again, when I was a child I was probably doing more physical things. You know, sports and stuff like that. I don't know that I would jump off any thing or things like that, but intellectual things I suppose, are different.

INTERVIEWER: Do you usually give them-- students-- be they undergraduates or graduates or even postdocs specific questions that will be theirs to try to answer when they come in, say the way Judah Folkman seems to have done with you?

LANGER: Absolutely. Yeah, I mean, that's what I do. I encourage them to come up with other things too, but I absolutely give them specific things to work on.

INTERVIEWER: And how do you find a fit or do you not just worry so much about that? You say, here's something or here are three or four things, any of them appeal to you?

LANGER: Well, I think students often come with some idea of a general area they might want to work in, like nanotechnology or regenerative medicine. So I might pick something in an area like that.

INTERVIEWER: Do you take in any high school students?

LANGER: We have, yes.

INTERVIEWER: These are people generally who are aiming for Intel projects or Westinghouse?

LANGER: No, not really. I mean, a lot of times it's people who have projects that they might want to do. We've had a number of high school-- like sometimes it's summer jobs and things like that. Sometimes it's a spring project. It's not something we do that often, but if they're high school students and in particular, if they're 18 there are certain liability issues. We've done it.

INTERVIEWER: Does there have to be some threshold that they need to be at in terms of knowledge or skills before they can really be participants and do you have a clear sense of what that is?

LANGER: I think it helps to have that but I don't feel that that's absolutely critical. I mean, it depends on the situation.

INTERVIEWER: How would you describe your role at the lab today? How much time do you spend as a manager versus as a researcher? Do you do hands-on research at this point?

LANGER: I don't really do hands-on research myself, but I spend a lot of time brainstorming with the students and postdocs. And then I guess I spend a lot of time giving advice. I mean, that's what my wife says. And I suppose when you look at the *Nature* article that's probably true. I spend a lot of time doing that. So those are the things that I probably spend the most time doing, thinking and brainstorming and giving advice.

INTERVIEWER: Do you miss the hands-on part or are you happy enough to do more of the thinking and let someone else do the--

LANGER: I don't miss the hands-on part. I'm not sure that that was ever my real strength either. I think I'm more of an ideas person. I don't think I've ever been exceptionally good at using a pipette or things like that. I think other people can do hands-on stuff as well, if not better than I can.

INTERVIEWER: At some point you were talking about your work having become not just respectable actually, but highly respected. You've won nearly 200 awards, maybe more than 200 by now including Charles Stark Draper, which is sometimes described as the Nobel Prize for engineering. Last year you won the Millennium Prize, which is described as the world's largest technology prize. Was there some turning point, do you recall sort of what you went-- suddenly people were scornful or dubious, I guess, maybe, and then all of a sudden was it one or two papers being published?

LANGER: Well the papers had been published. I think you're right. People were scornful of the work early on. I think time takes care of-- that you know, in the impact that those papers would make over time. But I don't know that there was a particular point in time. We talked a little bit earlier about getting tenure and I think certainly you'd start to see a change in people's attitudes even then. But I think, over time what's happened is the impact of those papers and of our discoveries and inventions increased. You never know what's going to happen, but I think the very fact that they would keep increasing over time probably affects that recognition.

INTERVIEWER: Has winning all of the awards made any difference in either your research or your life?

LANGER: Well in my research, I don't think so other than that probably even enhances further the number of people who apply to your lab. It also, I think gives the areas that we work in, like bioengineering and biomedical engineering maybe more respectability in the world. As I recall, the Draper prize-- mine is the only time it's ever been given in bioengineering. I mean, usually it's in some type of computer or internet thing. So I think it helps in that. In terms of my life, you get a certain amount of money for these awards and that's, I think, a nice thing and it makes you feel better and even my mom feel better.

INTERVIEWER: You'll be able to afford college for your children?

LANGER: Yes, yes. We can do that, though MIT helps you on that.

INTERVIEWER: You also pop up regularly on lists of extraordinary people. Again, to list a bit, *Forbes* said you were one of 15 innovators who will reinvent our future. *Parade* magazine called you one of six heroes whose research may save your life. *Time* magazine called you one of the hundred most important people in America. Were you surprised when you started being recognized in this way and did these lists affect your life? And have you found any way to use it as a bully pulpit? You talked about the role of the media in terms of trying to bring young children into science. Are any of these useful in that respect do you think?

LANGER: Well, maybe to go backwards. I think that whether they want to publicize me or other people that use science to help people, to me, is good. And actually, always when I get calls from the media I try to be really responsive. I just think that's really important. And I also always like it to be accurate too. So to me it's not like I could use it as a bully pulpit, I don't. I mean, I don't even know how I'd do it. But I think the very fact that they would devote issues or covers of *Parade* to people doing medical things that are helping people I think is good, whether it's me or anybody. And the same thing for all the other things like *Time* and *Forbes*. I don't think it changes your life in a fundamental way, but I think it's nice. I mean, it makes you feel good and it makes your family feel good.

INTERVIEWER: Let's turn to the economics side and business side of what you're doing. We talked about how many patents you have already or in process, and a lot of them have been licensed or sublicensed I think to more than 200 companies at this point. What does that involve and how involved are you with the licensing process and the licensees once they get them?

LANGER: Well, basically, so we in our lab have a lot of patents. You know, it's students, the postdocs, myself. So we file a patent. MIT has a terrific Technology Licensing Office, I mean, probably as good as any in the country and so they do it. Sometimes somebody comes to me and I would make that introduction and have them talk to the people in the licensing office. But sometimes what's happened is it's just the license and then we might get a grant from the company and that's great. Sometimes the company might start based on one of these technologies and I'm often involved in helping that happen too-- you know, maybe as a founder of a company or member of the Board of Directors or member of the Scientific Advisory Board. And so it really depends on the situation. But to me those are also really good things because if companies pick up what we do, the chances of them making an impact are that much greater. So I guess I want to do whatever I can to help.

INTERVIEWER: Some universities have earned really significant revenues from patents and royalties, from discoveries by their professors. In some cases, NYU right now and Columbia had a long running profitable patent, hundreds of millions of dollars. Do you think any of yours have that kind of financial potential?

LANGER: Well, I don't know if any-- I mean, I hope so. And some of them already have brought in some substantial amounts of money. Not necessarily through sales, but also I think MIT has taken equity in some of the companies and I think that it's not hundreds of millions of dollars. In some cases I think it's led to many millions of dollars.

INTERVIEWER: Do you remember what your first patent was?

LANGER: Well, the first one we filed was actually on what we talked about before, controlled release of large molecules.

INTERVIEWER: With Judah Folkman lab? So that one's expired by now? They have, what? 17 year lives?

LANGER: They did. Now they'd be 20 from the date of issue, from the date of filing. But then it was 17 for the date of issue. You're correct.

INTERVIEWER: You mentioned that you're engaged in a variety of startup companies, what's that like? Do you remember the first one? Can you walk us through a recent one?

LANGER: Sure. Well, I'll give a general idea and then I can give you a specific-- I can go through the first one. I mean, it's fun, it's exciting, and it's important. And almost always I've been able to do it with my students and postdocs and work with them and my friends and colleagues. Basically, what I'd do is-- like if we had an idea and one of the students or postdocs wanted to start a company and I thought it made sense, that it was far enough along, I might talk to some venture capitalists and some of my students now are venture capitalists too. Which former students are venture capitalists. And I'd make that introduction, the venture people might talk to MIT. We'd try to put something together and rent some space and try to create that technology. So just as an example, let's see. The earliest one was Alex Klibanov and I had this idea about using microspheres in different areas and we formed a little company called Enzytech. And the idea would be to use microspheres for drug delivery and also in the food area. So four of my students began to work there, we got venture capital, and we got a CEO. We rented some space. Over time what would happen is the drug delivery company merged with another company and they now make these microspheres. Some of them have been now used in treating different diseases like schizophrenia, alcoholism, cancer, things like that. So they've done quite well. The one that was doing the food work actually went public, made things that were like microspheres for fat substitutes and things like that. Eventually they got bought by a very large food company. But they're both still around doing well.

INTERVIEWER: How did you learn about the business side of all this? Did you have to go read some books on finance? Or did you have a friend who sort of guided you through all this?

LANGER: I think neither. It's really trial by fire, learning by doing. I did learn something by being an advisor or consultant to companies, but really I had no idea. I mean, I would just do it and probably make my share of mistakes and learn from doing that.

INTERVIEWER: Are there any mistakes that you've talked about? I mean, big mistakes that you say, oh my goodness! in hindsight. How could I have done that? Or gee, I wish I had known?

LANGER: Well, all kinds of things. I mean, I'm not even sure where to start. Let me just start with licenses rather than companies. You know, when we first had that patent for controlled release of large molecules I remember we licensed it to an animal health company, a multibillion dollar company and they gave me a $200,000 year grant. This was the early 80s and it was wonderful. And they gave me a consulting fee. I thought, this is great. But then they didn't do a very good job of developing it and then a year later another company, one of the largest pharmaceutical companies in the world licensed the technology now for human health. And I remember they did a couple of experiments and it didn't work and they kind of just gave up. But again, I got a big grant and I got the consulting thing, so I was excited about that. But I was frustrated by the fact that it didn't work. I'm sorry, that they didn't, the company didn't push it. And that coupled with some other experiences being involved in small companies made me realize that these small companies just have the passion and sort of this live or die attitude on these technologies, and so one of the lessons I learned was that small companies-- at least in the United States could really develop these technologies, which are still pretty early. In many cases, much larger, much better than large companies even though the large companies had the resources. Be lots of other lessons you'd learn too. Just having to look at how do you make sure that the companies keep developing these technologies, whether they are large or small? Others are more intangible. How do you find really good business people to work with? That's extremely hard, but critical. I mean, having the right business partners is one of the most, probably the most important thing, when I think about these companies. So there's just lots and lots of lessons.

INTERVIEWER: And how do you find the right business partners? You've tended to work with some of the same ones over and over again and maybe they're responsible then for filling out the blanks?

LANGER: Well, I work with some of the same venture capitalists over and over again. And that took some time too to realize the venture capitalists I'd like to work with most. And I do a lot with Polaris Ventures and a lot of that has to do with really the way they've treated me and treated other people. And what you've said is correct. I mean, I help on finding the CEOs. CEOs is part of what I mean, but I think that a lot of times they're better at it than I am. So you kind of all work at it together to try to figure out who's really the right people who are going to lead the particular company.

INTERVIEWER: And these tend to be people with background in science or background in business, or both? Is there any formula?

LANGER: I don't think there is a formula. And when I look at great CEOs I don't know that there has been a formula other than that they've been passionate, they've been very smart, they worked incredibly hard, they may dream. But there's no formula in terms of their exact discipline.

INTERVIEWER: Have you ended up doing anything with the Sloan school of business at MIT in terms of helping to educate some of the people who come through about what it takes to do things like this and how important it is in a way if it's going to get out to people?

LANGER: So there's the Sloan fellows program and I think I give a lecture to them every year. And I give examples of companies, so I think that they keep wanting me to do it so I guess they must think the lecture is okay. And then a number of the Sloan fellows, actually I've been involved in helping a couple of them start companies-- you know, by introducing them to people in our lab and maybe helping them get started.

INTERVIEWER: It seems like as the number of these business ventures grow, as your number of patents grows and you look for ways to bring them to the real world, they have the potential for eating up all your time. How do you juggle it all? I mean, you're on their advisory boards and their boards of directors and you're running this bigger lab and you're teaching.

LANGER: Hasn't gotten to that point yet, but I think what happens is that I kind of view these companies as almost like children growing up. And when you start them they need a lot of nurturing. As they get a little bit older they need a lot less and as they get a lot older they may not want any at all, or they may want a little bit, and I'm happy to do whatever works for them. But I found that as they've grown bigger and stronger, my time commitment is much less. So really the time that it takes is mostly in the earliest stages. And so you just don't do 10 at once. So I've been involved in many, but it's been over a fairly long time.

INTERVIEWER: Do you run any kind of seminar at the lab for how to get started on the business side? You have so many people, including so many young people, is there a training function there?

LANGER: There isn't exactly, but one of the things that the postdocs have had me do and sometimes the graduate students, which I enjoy doing, is we have different topics. You know, one could be how to find an industrial job or how to write grants or how to get a position, or could be with the company things. So I talk a little bit and then they ask lots of questions and usually over pizza for a couple of hours. So I think those kinds of things-- so it's not like a formal seminar, but there's a lot of interaction.

INTERVIEWER: And is the final line of advice worry about the science and engineering first, the rest will come later?

LANGER: It really isn't. I don't think there's a single piece of advice. There's many. And I also think that the science and engineering are important, but it really isn't the only important thing. I really think understanding, having the right business partners-- I think the companies are very different, especially in the medical area than the things that we do in the lab. And even though this is a little bit off topic in terms of what you're asking, I mean, what I would say when I look at successful companies, probably that some of the companies that I can think of that have been incredibly successful-- they don't even end up doing close to what they did, what they've proposed to do originally. But because their business people are so good they've been able to raise a lot of money for their initial idea and then they were able to acquire other things.

Just to give an example, like you could take the genomics area. And I'll just pick Millennium as an example. I was an advisor to them. So Mark Levin, who's actually an engineer, he's from Wash U. He was a CEO of that and he's just an outstanding guy. And he raised tons of money. I think today the genomics stuff that they acquired-- I mean, that didn't lead to nearly what I think they hoped. That it was based on what they hoped to achieve. On the other hand, they acquired some companies that were struggling and some of those companies had some very good drugs like Velcade. And they ended up becoming an incredibly successful company. So I think that it's the combination of good business and good science.

INTERVIEWER: Has the downturn in the economy and the financial markets affected the pace of the commercialization of some of your work?

LANGER: I don't think it's affected it too much. I think you do struggle a little harder to raise a lot of money, but I think it still seems to be happening at a pretty good pace.

INTERVIEWER: You talked about the various relationships with some of the companies that were trying to commercialize your work. I think there's been growing recognition of the importance of bringing scientific findings, particularly from universities to the marketplace, and there was the BiDole Act back in the early '80s. But at the same time there seem to be growing concerns about whether there are potentials for conflict and whether some universities have occasionally overstepped lines that critics are unhappy with. How much does this concern you and what do you do about it? How do you think about it?

LANGER: Well, I think it's a concern. I think MIT is in a somewhat different place. I think the biggest time conflict of interest occurs are for clinical people where they may be doing clinical trials and hold equity in some company. I think MIT has pretty clear rules on what to do and I think those rules are by and large, fine. In fact, I think even conservative. But my feeling is whatever the rules are is what we'll do. And I think the rules are total disclosure to MIT and you don't get grants from companies you hold equity in. Again, at a pretty high level, some of the key things. So I think that's fine.

I think though, to come back to one of the things that you and I talked about earlier, it's disappointing to me that the newspapers and media give so much attention to conflict of interest when I would rather see them give attention to how science can really help people. And the same thing with senators. I guess I wish rather than them paying-- so I'm not trying to say it's unimportant, I think it is important. But I think in the scale of things it's not nearly as important as making young people think that science is something and engineering are things that can be wonderful and change the world. So I think the amount of attention that it's given, both by the congress and by the media is disproportionate to its importance. Usually it's a very, very tiny percentage of people that engage in things that might cause problems. Whereas, if you had a lot of great scientists and engineers they'd be doing all kinds of great things for this country and the world.

INTERVIEWER: Do you run into companies that want sole control over a set of ideas or the research they're financing and how do you handle that?

LANGER: The answer is yes. But MIT is usually pretty good in terms of the Technology Licensing Office of saying, well you have to spend a certain amount of money per year to develop it. So they craft the licenses, I think, in ways that really cause the companies to not be able to do what you said, unless they had spent an enormous amount of money, and if they did, then maybe that's okay. But in other words, I think MIT's TLO, they tie these things to really making sure the companies develop it in the best possible way.

INTERVIEWER: How do you know when something is ready or has good potential? Do you go knocking on doors or do they come to you, does it depend on publications?

LANGER: The rules that I've used-- I think, Harvard Business School did do a case study on it. I basically pick the following rules, which may not always be right but I've said what we want is what I'll call a platform technology meaning you have a technology that can be used over and over again, but just change the drug substance, for example. The second thing is that it lead to products say, more than information. The third that it be published in a very high profile journal like *Science* or *Nature*. And I don't mean it to be just to have that kind of snob appeal, but I mean that it really be some kind of breakthrough. And fourth that we have patents that flow out of those publications that are really broad blocking patents. And fifth that we have really convincing proof in animals-- not just like test tubes or something like that. And I think if we have all those things and then some of the students or postdocs in the lab really want to do it, then I generally feel it makes sense. There are a lot of venture capitalists that do come to ask us what we're doing. In fact, a lot of them know anyhow because they worked in our labs and now are real life, full-time venture capitalists. And they're still very much in touch with me and other people in the lab.

INTERVIEWER: How many commercial ventures are coming out of the lab? Is there an average or something typical per year?

LANGER: Well, I would imagine maybe it's one, at most two per year. But then there are also licenses as well. That might be more.

INTERVIEWER: Has the internet made much difference in terms of the sharing of information or publication? I mean, you just mentioned that putting something in a high profile journal is important, but I wondered given the turmoil in the whole area of media whether that's changing?

LANGER: So to me, making sure that scientists think it's really great, really breakthrough. I still think today being in *Science* or *Nature* is what it was back when Watson and Crick published their stuff and before. I think that those journals are just outstanding and a lot of other journals are very good as well. I think the internet does able you to get information about all kinds of things, but that doesn't mean that the quality of information is necessarily good. It could be in some cases, but the great thing about the top journals is the review process they go through and that insures the quality most of the time.

INTERVIEWER: The internet I think has changed the ability of researchers in-- well, internet and digital. Changed the ability of researchers to do research. Linguists for example, are suddenly, with the digitization of back journals able to look up things they couldn't in a way. Is it changing the ability of your researchers to sort of stay on top of different things or to find ways to do different things instead of just sitting in the lab and thinking about it and trying? They go online and say, oh, he's trying this or she's trying that?

LANGER: I think it helps you do searches. I think it does help you find information faster, yes.

INTERVIEWER: You've written a lot of articles. I guess, about 1,000 and 13 books, and I guess, some of these may be coauthored. Are any of them aimed at the public? Do you ever think about writing a book for a lay audience?

LANGER: I mean. I guess the question is, like I've written a number of things for *Scientific American* and other places at that level. I mean, beyond that I haven't. I guess I'm not sure that I'm really that great a writer. I mean, in fact, when I write for places like *Scientific American* or places like that they always have editors or writers who take whatever I write and make it much more understandable. But if there was a way I could help I certainly would be happy to.

INTERVIEWER: Are there any big popularizers in your field at this point? I mean, I'm thinking of the work, somebody like a Steven Pinker has done in terms of writing for a broad audience or John Kenneth Galbraith in economics. I don't know--

LANGER: I don't know if there are. I mean, I know what you're saying, I think. I don't know if there is anybody that's done that.

INTERVIEWER: You mentioned that you're about to-- I don't know if about-- that you're going to be moving into the new Koch building and setting up. How soon is that and what's it going to look and will that change your lab or your style at all because you're starting new?

LANGER: That's supposed to happen in a little less than a year from now, in December of 2010. I don't think it'll change my style. I think it'll be a great thing. I mean we'll get more lab space, we'll be in the same building with not only other engineers, but some of the top biologists at MIT. So I think it'll be great for our students and postdocs to be in a place that's really going to expose them on a day- to- day or hour- by- hour basis to really top biologists. So I think that'll be a terrific thing.

INTERVIEWER: How much more space are you getting? Is it like a third more or half more?

LANGER: Yeah, I think we go from like 14,000 to 20,000, something like that.

INTERVIEWER: That's a big jump.

LANGER: Yeah, it'll be a big jump.

INTERVIEWER: Did you have trouble filling it or does everybody just get that much--

LANGER: They'll probably get that much more, but our space is very crowded now.

INTERVIEWER: So they'll spread out.

LANGER: They'll spread out a little bit more. You know, our space is super crowded right now.

INTERVIEWER: You'll hold on for another year?

LANGER: Well, I hope so. I hope so.

INTERVIEWER: Were you active in redesigning it or did somebody else carry that?

LANGER: I was involved in all the committees, but I don't want to give myself very much credit. I would give almost everybody else a lot more. So I was involved in it, mostly because they asked me to. I don't think that I contributed that much.

INTERVIEWER: And in terms of designing labs that facilitate discovery, were there other things that you said, we don't have this now, but it would be nice if...? Other than more space?

LANGER: Well, more space was the number one thing and the number two thing really comes down to me, the ideas. I mean, there are kinds of equipment that can accelerate discovery like high throughput things. But we've gotten some of those anyhow, and hopefully that'll be accelerated in the new building. But to me the number one thing is the people and I think the increased interaction of people with very different disciplines, I think will be a terrific thing for helping new ideas and discoveries.

INTERVIEWER: There have been one or two reports about your work with Julie Andrews and her synthetic vocal chords. How did that come about and where does it stand?

LANGER: Well, one of her surgeons, Steve Zeitels is at Mass General Hospital and he asked me a number of years ago, could I help him because there's many people actually that have vocal chord problems, Julie Andrews being one of them. But she herself has been very helpful. I mean, she's been to our lab a number of times and helped in different ways in terms of creating awareness and even helping raise funds for it. So where we are is that one of my postdocs has made a new gel, a new polymer that hopefully could be in patients within a year or two or three. We don't know exactly how quickly, but there has been animal testing now and the hope is that it could help for people who have scar tissue in the vocal chords.

INTERVIEWER: Can you test vocal chords in animals?

LANGER: You can do some things in animals. You can look at some safety and you can look at certain types of vibrations.

INTERVIEWER: Well, maybe we'll wait for her to sing at the opening of the Koch Institute.

LANGER: Well, we'll see.

INTERVIEWER: Thank you very much for your time.

LANGER: It's my pleasure.