INTERVIEWER: Today is August 10, 2011. I'm Barbara Moran, and today we are at the MIT Studio speaking with Angela Belcher as part of the Infinite History Project. Professor Belcher received her BA in creative studies from the University of California Santa Barbara in 1991 and a PhD in chemistry from UC Santa Barbara in 1997. She joined the faculty of MIT in 2002.

Professor Belcher is now the W.M. Keck professor of energy at MIT. She is a materials chemist with expertise in the fields of biomaterials, biomolecular materials, organic/inorganic interfaces, and solid state chemistry. In her interdisciplinary work, Professor Belcher seeks to understand and harness nature's own processes in order to design important materials and devices for energy, the environment, and medicine. She has won numerous awards for her work, including a MacArthur Genius Grant in 2004. Welcome, Professor Belcher.

BELCHER: Thank you.

INTERVIEWER: So I wanted to ask you to start off by telling me about the first time that you encountered abalone.

BELCHER: Wow, so I grew up in Texas, so I didn't actually encounter abalone in Texas. But I was interested in minerals and pearls and beautiful natural structures. When I was an undergraduate at UC Santa Barbara-- it's right on the ocean, it's actually really beautiful-- and I learned about how abalone shells are interesting materials. They're strong and tough structures. And so I didn't really counter abalone until the very beginning of graduate school when I went to visit an abalone farm in Santa Barbara. It was inside a laboratory. And I learned about the unique properties of the inorganic structure and organic composite of an abalone shell. And they had the little organisms that are actually swimming around in the little abalone condominiums in the marine lab there. And it was really a perfect project for me, it was really love at first sight.

INTERVIEWER: Great, that's what I was going to ask you. I wanted to ask you a little bit about your upbringing and growing up in Texas. So just tell me a little bit about your upbringing.

BELCHER: I grew up in Texas. I grew up a seventh generation Texan, I grew up between Houston and San Antonio, kind of back and forth between the two. I have an older brother. I loved science from very early on. As a child I wanted to be an inventor. And I didn't really exactly know what that meant, but it was a strong force inside me. And I would go into our garage in Texas where it's 100 degrees in the summer. And I would say, I'm not leaving the garage until I invent something new. And I would be out there working with whenever I had in the garage that belonged by my parents. And I never really came up with-- I had ideas drawn, sketches drawn, but never was able to produce anything. But it was always inside me that I wanted to be an inventor.

And I was also really interested in genetics early on. I have no idea where I got that from, but I would buy genetics books and try to understand it. So that was also something that was interesting to me. And I also grew up not far from Rice Library and I used to go there and check out books and try to learn more about science.

INTERVIEWER: And were your parents engineers or scientists?

BELCHER: Neither of my parents were in science and engineering. I'm not sure exactly where it came from. As I got a little bit older, I was in the Texas Medical Center in Houston and a couple blocks from the hospitals, and one of my next door neighbors was a radiologist resident. And he would take me with him to the hospitals and I would get to go on rounds. And I actually even got to go into some surgeries and wear the white coat. And so pretty early on I thought, well maybe I want to be a physician. And I thought that was a very good profession, helping people and getting to do science at the same time. And so I was interested in that, and I would actually learn a new disease every day. I'd call it the Disease of the Day, and I'd try to learn it on my own and read medical textbooks. When I started college, I thought I might go into medicine.

But pretty early on, I fell in love with large molecules and proteins, actually. And it was so captivating to me. For the first time, I started thinking about a protein in solution in its surroundings, I couldn't turn back. That's what I knew I was interested in.

INTERVIEWER: Were there any kind of-- I don't know the right word-- but values or lessons from your parents or lessons from where you grew up that you feel like shaped you, and shaped the way you work and the way you do you work?

BELCHER: I think that the idea of hard work was very important to me and to my family. And I started working when I was 13-- I started working at Baskin Robbins-- and then I was at floral design, and I strung tennis racquets, and taught tennis at tennis camp, and started working hard and saving my money. And I knew that that hard work was going to get me far. And so that's something I've always been interested in. And I also started a little camp for kids when I was, I guess, 11. 11 or 12, I got written up in the newspaper. And so I was always interested in entrepreneurial aspect and hard work. And that's something that I try to teach my kids now, is that you can be really smart and be really creative, which is great, but I think the work ethic and hard work takes you a long way.

INTERVIEWER: It seems like you were quite a precocious child-- starting camp and going off to the hospital. Were you the smartest girl in school?

BELCHER: I think I was pretty normal, actually. And I think that I've always been very focused. It's interesting looking back, because I talk to my husband-- we went to elementary school together-- and he seems to think I was one of the smartest kids in the class. I definitely didn't feel that way. I felt pretty normal, and I felt always very driven by my interests. And I never really cared what people thought. I just thought science was interesting and I thought business was interesting, and that's what I was going after. I think I was pretty normal.

INTERVIEWER: I had read somewhere that you were dyslexic?

BELCHER: I'm dyslexic. And it's kind of strange, because I didn't know when I was very young that I was dyslexic. I felt like kind of a slow reader. I do remember getting extra tutoring in reading from my aunt, who was a teacher. And I don't think at the time they realized I was dyslexic. And I have a really fantastic memory, and so I just memorized all the words. I never learned phonics and how to sound things out.

It's one of those kinds of things that today, I feel like it's one of my biggest advantages and disadvantages at the same time. It's an advantage because I do have this really good memory, and I do have a way that I think is interesting of processing information and thinking about things that I may not have had if I wasn't dyslexic. It kind of forced my brain to work in a particular way. At the same time, I'm very slow at writing emails because the dyslexia does slow me down in terms of writing. But I think overall, I feel like it's been an advantage. I really like the way that I think and lay things out in the creativity. I think it's kind of playing to your strengths, which is something I've always been a big fan of.

INTERVIEWER: That's really interesting to me, because I was wondering if that was the case. If not relying on the written word so much, if there was something about-- because your work is very creative, and the ability to put these different fields together, and I was wondering if there's-- I mean, I wonder if you'll describe a little more about your--

BELCHER: Thought process?

INTERVIEWER: Yeah.

BELCHER: I think I'm just a dreamer. I'm a dreamer. I like to think about what's possible and think about different fields. My degrees are in different areas and I've always thought about how to put them together. And I don't know how other people think because I haven't really done any studies in it, but I think in graphics and I think in patterns and colors. And when I'm thinking through a new idea, it's almost like looking at it projected onto a screen. I can see how all the pieces come together. That's just the way that my brain works. And I'll take an idea and move it around in the projector in my brain in three dimensional space and see how the pictures snap together and fit together. And then kind of push it forward and see what the possibilities for the outcomes are.

And when I'm actually describing a new idea or brainstorming with my students-- which I do a lot because I have very smart students-- and we sit together and brainstorm on new ideas, I do that. I take the pieces and I project it out and say, this is how I'm thinking of it. I'm thinking of the structure or thinking of a way of having biology make a new material, and kind of just go through in my mind clicking it together and looking at it on a screen. And when people talk to me a lot of times, I'll be looking off to the side. And they're like, what are you doing? And I'm like, well I'm kind of looking at it, seeing how it looks when it's projected. So I don't know if that's normal or not, that's just the way that my brain has worked, and it's worked fine so far.

INTERVIEWER: What if there's any societal events from your upbringing that shaped what you want to do at all.

BELCHER: I wouldn't say that that's exactly the case, but I always felt like I wanted to make a difference in the world. And that's always been very important to me, that I want to do something that does benefit society. And I think that's why I was interested originally in medicine, because of the human aspect and helping take care of people, especially in hard times. And I was really driven by that originally. And it was a little bit hard for me when I came to the conclusion that that wasn't what I wanted to do when I was 18 years old. And there was a guilt associated with it, that I was much more interested in molecules.

And so for a while, I thought, well I'm going to do both. But as I was going down the path, I realized that molecules are wonderful too and there's so many things that you can do that do have a benefit on society. At that time, when I was 18 and 19 years old I never really thought that I would be using molecules for energy and using biology to create new materials for energy. But I think that I've always had this overwhelming desire to make a difference in the world.

INTERVIEWER: That's interesting, and that brings me to my next question. How did you end up at UC Santa Barbara, and how did this shift from medicine to science happen? Was there a particular teacher or class, or was there a moment when you fell in love with molecules and felt that that was the way to go?

BELCHER: I think it was from the very beginning. I went to California just as a 17-, 18-year-old wanting to leave home, looking east and looking west. And California looked very nice. And Santa Barbara was a really great fit for me. As you mentioned before, my degree is in creative studies, which was a design-your-own major. And it was great for me, because I was interested early on in the origin of life. What were the interface between the first molecules and how they became self-replicating molecules, and did that happen at the interface of inorganic materials? So I was interested in that from very early on.

So that kind of took in, I was interested in geology, I was interested in chemistry, I was interested in biology, and I didn't want to choose, basically. So I went into this program that was design your own major, that you could put things together however you wanted. And that, I think, had one of the largest impacts on my career because I could see early on that it's okay to put these different disciplines together in ways to solve problems, and it was actually encouraged. And so I did. I worked in physics labs, I worked in biology labs, in ecology and biology and chemistry. And it really started giving me the idea of putting these different tools together to solve problems. So it was one of the best decisions I've ever made, was to go to UC Santa Barbara and major in creative studies.

INTERVIEWER: Interesting. You could see, though, how that could go terribly wrong and you could just flit around in a million different things. So I was wondering if you had someone or several people guiding you or mentoring you.

BELCHER: Yes, I did. You had a mentor who was an academic mentor, but then I was also in, from the very beginning as an undergraduate, in research labs, similar to what we do at MIT. We try to get the students into research labs as soon as they want to and as soon as they have time for it. And so I worked one-on-one with several different faculty there. To me, it was a blast.

INTERVIEWER: And they were supportive of this interdisciplinary idea?

BELCHER: Yeah, very supportive. And UC Santa Barbara is a very interdisciplinary place. And that's where I academically grew up. I was there for undergraduate, graduate, and postdoc. And this idea that there aren't boundaries between fields is very much a part of their fabric. And I remember as an undergraduate, I had keys to the physics department, the biology department, the materials, the engineering. And it was really great because I could go different places and use different equipment and it was a very supportive environment. It's hard to mention people, because there are so many. It was a great experience, there was so much one-on-one time with faculty there that it was a great experience for me.

It gave me a tremendous amount of confidence very early on. I remember when I was an undergraduate in a molecular biology biochemistry lab, Jim Cooper's lab in UC Santa Barbara, we were doing polymerase chain reaction and it was a way of trying to amplify particular DNA sequences. And I was like the second or third person in the whole building to do this, and I was a young undergraduate. And I was reading the manuals and trying to figure it out. And we only had one instrument in the whole building, and now we have a couple of them in my lab.

I remember barely being able to sleep at night, couldn't wait to try the experiments. And that's always been the way it was for me. And just how encouraging Jim and lots of other faculty were there in terms of-- I think, to me, that's been the key to my success and my career, is just absolutely loving what I do and being so excited about it. And there's so many days even now that I go to sleep thinking, I can't wait to see what the results are like tomorrow. What a wonderful existence that you love your job so much that you just can't wait for the next day to see what's happening. And I felt that from the very early time of being an undergraduate, just the excitement of discovering something new or trying to find how pieces fall into place.

Maybe part of that is innate in me, but I think part of it was the early mentors that I had that were just as excited about what I was doing or the research was going on in their lab. That's been absolutely key to me. I can't imagine having a job where, oh, it's just a job. For me, it's not just a job or career. it's a life, it's excitement. Every day, there's something new. And not every day is a great day, there's days where things just go wrong. But I learn 10 things a day, I learn something new. It's really a great place to be.

INTERVIEWER: Great. So tell me, eventually you ended up steering toward chemistry and did your PhD on abalone. And so tell me how that came about.

BELCHER: Well, it came about by-- it's kind of an interesting story. I worked in a physics lab some as an undergraduate in UC Santa Barbara with a professor, Paul Hansma, who was also a physics professor. I took him for a physics undergraduate course, he's really fantastic. And he worked on atomic force microscopy, and built some of the first atomic force microscopes that could be used to look at many different things, including biological samples. And when I took it, his class is one of those classes that you take and then you know that that's what you want to do. So I took his class, his physics class, and said okay, now I'm sure I want to be a physicist. And by this time, it was my junior year. And I went to talk to him and I said, I'm sure I want to be a physicist now. And he said, well, you know you only have a year and a half left. Why don't I introduce you to some of my chemistry colleagues? Afterwards, I'm like, wait a minute.

So he introduced me to Galen Stucky, who is a chemistry professor at UC Santa Barbara who is fantastic, dynamic, really pushing the boundaries of new materials. And he's a big thinker. And his excitement for science is contagious, as Paul's was. And so I started talking to him, and he was really wanting to go more into the bio end of things, bio and organics, so I was a good fit. And so then he introduced me to professor Dan Morris in the marine science end of things, but material scientists and a biochemist as well. And these three people-- Paul, Dan, and Galen-- were all working together on starting to work on abalone shell. And so I got pulled into that project from starting to isolate the proteins involved in abalone shell. So I got to work with three people. Basically, I had three advisers from my PhD who were all from different disciplines. And they all had a really great working collaboration, got along well together, and they were all just enthusiastic and excited about the project. So I kind of got swept into that.

So I started working from trying to find proteins that can control inorganic structures, so working between all three of them, so it was kind of a dream come true.

INTERVIEWER: Yeah, that really makes a lot of sense, actually. How that set the basis for, really, the rest of your work. And having that interdisciplinary thinking there. Yeah, that makes a lot of sense. But the postdoc in electrical engineering, that I don't understand.

BELCHER: So I worked on the abalone shell. And one of things I wanted to say about that was that-- and this is something that was a lifelong lesson to me-- is that when we work on the abalone shell, we had groups of physicists, chemists, biochemists, molecular biologists all working together. We'd have meetings every Wednesday at noon where all the team would get together from all these different disciplines. And one of the things that I liked about it is all three of these faculty were top of the field in what they did, but we kind of had a rule that when you walked in that door, you left your ego at the door.

And so you'd have a biologist-- maybe it's a graduated student up at the board-- explaining something about biology, as they think related to the abalone shell. And then you'd have a physicist up there explaining something about the physics of it. And so we spent a couple of years doing that until we all could speak the same language, and it was a really, really fantastic experience. So I was very, very happy about my PhD.

And then for my postdoc, I really chose it based on a person. It was working with professor Evelyn Hu at Santa Barbara at the time, she's now at Harvard. And she's a fantastic mentor. She's a physicist by training, but was in electrical engineering and material science. And she's a big thinker, and I wanted to work with her. And so she took me into her group, and no one had had any biology background in her group before. And it was a big learning curve for me to learn to fit into her group. And some of my original ideas that I was thinking about on how to interface biology with semiconductors didn't really work out. But it was a great learning experience, which originally led to what I do now, which is selecting and evolving organisms to work with electronic materials.

It's one of those things where you have to jump in with both feet and you have to leave your ego at the door, because you're going, I know nothing about this. What can I learn? And I try to approach things that way a lot now because I can think, well, do I know enough to enter this area? I think what you have to do is decide, this is something I want to learn. This is something I want to do. Jump in with both feet and then work with really smart people in that area that can then help figure out how to interface it and if there's an interface and how to push it forward.

INTERVIEWER: It's interesting how that set the whole groundwork. It seems to me like a lot of people do a PhD thesis that then has nothing to do with their subsequent work. So it's nice that this all really built the foundation of what you're doing.

BELCHER: You know, I'd love to say I planned it, but I didn't plan it. I just followed what I was interested in. And that's always been my approach, is to just go with what I'm interested in and get into it and see if I can make a difference in that area. And that's exactly what we do now. It's like, oh, this is interesting. Can we have an influence in solar? And that's how we just approach things.

INTERVIEWER: So afterward, you went back to Texas. How did you end up going from Texas to MIT, how did that come about?

BELCHER: So I went back home to Texas and I was at University of Texas Austin-- the chemistry department is a fantastic department there. And things were going really well. I wasn't really on the job market because when I finished my PhD, I didn't apply for a lot of jobs. I got a job at University of Texas and it was a great opportunity, and so I went there. And once I got there, I started being recruited by other schools because I wasn't on the job market so they hadn't seen me before. And one of the places was MIT. And I had no intention of coming to MIT, I didn't know what MIT was like, but it just didn't sound like me.

And so I flew out to give my seminar and told my husband, don't worry, we're not moving to the East Coast. I'm just going to go see what it's like and then tell them I'm not interested. And I flew out here and I absolutely loved it. I gave a seminar, I loved the faculty, the students, the projects. I looked around and it's one of those places where you think what everyone else is doing is incredibly interesting and you want to work with them. And that's what it was like. I always say it's like Disneyland for scientists and engineers because I looked around, I go, wow I want to do that, I want to do that, I want to do that. And so I flew back and told my husband that I really liked it. And he says, well that's good, but let's not really think about the East Coast.

So I came out for second interview out here and I loved it even more. And I think I actually came out for a third interview to fly out to say I wasn't coming. And during that time, it was at a Starbucks, I was talked into coming. And I had to fly back and tell my husband we were moving to MIT. Because it's one of those kind of places that there's so much exciting happening here, I didn't want the opportunity to be left. I wanted to be involved in it. And it really had to do with the development of the biological engineering department here. The way that they looked at biological engineering, the way they looked at the world really resonated with the way that I looked at the world. And that, combined with the material science department here, it just seemed like it was the absolute perfect fit for me.

We've been here nine years now, and we keep saying, well one day when we go home-- and we say, we'll never go home. This is too great for us.

INTERVIEWER: Now, when you said that originally you thought that MIT didn't sound like you, and you seem to have this issue with the East Coast.

BELCHER: Well, I just grew up in Texas. I'm a seventh generation Texan. And I didn't want to live anywhere that snowed, for one. But that way it didn't sound like me. I thought MIT was going to be kind of a snobby place. And I don't know why I thought that, I just did. And I thought, that's not really my personality. But it's not like that at all. And that's one thing that I love about MIT. What matters is how good you are and what your ideas are and how hard you work. It's not where your family's from, it's not where you went to undergraduate school, it's all about your ideas and if you can make them happen. And I like that. It's what you can do, what you can bring to the table, and how well you work with other people. That's the key to success here. And I like that a lot. So it's very much me. I just didn't know.

INTERVIEWER: And is your husband also a scientist?

BELCHER: Yeah, he's a physician. He's at UMass.

INTERVIEWER: And so how did you convince him? What did you have to--

BELCHER: You know, it's kind of funny because I think that we were saying where to go and we made a list. And I think I listed Boston one and he listed it last. I think that's how it happened. I think he was convinced that I completely fell in love with MIT and that it was the only place that I wanted to go. And Boston's a good place for medicine too. He also grew up in Texas and did all his education in Texas. And so I think that it was a place movement more than anything else, from his point of view. Because he ended up going into the residency in the Harvard Medical School system. And it's a great place for him to work. I think it was just the idea of moving away from our home and our roots. And we're very much Texans.

INTERVIEWER: Yeah, I can imagine that would have been difficult. And have you adapted to the snow yet?

BELCHER: We have. I don't shovel snow, my husband does that. But we do. And it's fun because my oldest has gotten into the snow for the first time this year. And he's done cross country skiing right out of our backyard. So that's pretty nice. The seasons are great. And Boston is a great city and Cambridge is great as well. I think it's mostly that we're both so happy in our jobs. And I'm so happy here at MIT that everything else kind of falls into place.

INTERVIEWER: I wanted to ask you specifically about interdisciplinary research. Do you find that MIT is quite friendly to that?

BELCHER: Oh, very much so. In making the decision where to go during my move, that was the most important thing for me. I was trying to recapture what I had as a graduate student in a postdoc in terms of no boundaries between disciplines and between departments. And one of the reasons that I liked it so much here is that it felt that way to me. And you can never really tell until you get here. My group almost never publishes a paper without collaboration from another group. We just love to work with other groups. And putting ideas together that are bigger than just us really amplifies the research. And so we work with people from a lot of collaboration here on campus.

And part of the new building that we're in, the new Koch Institute for Integrative Cancer Research is that way because we have half scientists, half engineers in the same building. And it's kind of a dream come true in terms of you can't walk down the hall without running into someone in a really different area than you. And it really brings about new ideas and this interdisciplinary relationship. And that's my favorite part about science, is I like working in areas that I can bring something to the table that maybe I'm not an expert in. But if I'm working with a person that's an expert in that and we work together, maybe we can find a way of thinking about something that people haven't thought about it before and have new approaches to solving problems. And that means everything to me, and MIT is just a perfect environment for that.

And I don't collaborate that much outside of MIT anymore. And it's not because I don't want to, it's just so easy to collaborate here. And if you're just in the same building or a couple buildings away, it's very easy to set up these interactions that can make a big impact in different fields.

INTERVIEWER: I heard you once say somewhere about the way you-- I don't know if you still do this now that you're in a new building-- but the way you actually organize your students physically and set them up in these groups. Can you talk a little about that?

BELCHER: So my group moved six months ago to the new building, and I let my students self-organize there. And so we didn't do that as much. But they seemed to organize not necessarily in areas of-- we didn't have our solar people and our battery people and our cancer people. They just picked the people they wanted to sit next to. So it's a little bit different now. But the thing that I love is that my students and postdocs-- most of them are in one big office with individual desks. And I'll be sitting there talking to one student about maybe our CO2 sequestration and storage project, and a student behind me is saying, oh, okay well what about-- and they're working on a completely different problem. And they'll throw their ideas into it.

So it's a really good interactive way of organizing ourselves. Because we have a small group and we're sitting there. And all the other students around, they either have their headphones, they're not listening, or they are listening and participating. And most of the students in my lab don't work on just one project. So a student of mine who just graduated, she worked on cancer and solar. And you say wow, those seem like very, very different-- actually, cancer, solar, and batteries-- they seem like very, very different areas. But they're not because they're all based on biological control of a specific inorganic material. And once we had good biological control of that specific inorganic material, oh, it works for batteries, works for solar, works for cancer.

And if we didn't have such an open-minded group, I think that would be hard for someone to say okay, I'm going to focus on this particular gene or this particular cell type. No, we're not like that. We're like, let's develop this material and see how many different fields we can impact with this one material. And that comes partly by-- I think I talked about interdisciplinary as being one my favorite things about MIT. But it's the students. It's the absolutely fantastic students that we get here-- undergraduates, graduate, postdocs-- picking the students who can think about ideas in a broad way. And that's very, very important to me. And I think that's the kind of people I try to bring into the group.

And the clustering that we have of students, I can look and say, there's a material scientist there, there's a structural biologist there, there's a mechanical engineer there. It's all mixed together in our group, and I think it brings a lot to an interesting way of solving problems, addressing problems.

INTERVIEWER: Now, do you still teach?

BELCHER: I do teach, yes. In the fall, I teach organic chemistry and biochemistry for materials with Professor Rubner, who is a fantastic teacher.

INTERVIEWER: Is that undergraduate?

BELCHER: It's undergraduate, yes. Sophomore, junior level course. And I also teach biological engineering labs in the fall as well.

INTERVIEWER: And tell me about, do you like teaching?

BELCHER: I love teaching. I do love teaching. The hard thing about teaching at MIT is that there's so many fantastic teachers at MIT. And you'd think that would make it easier, but it's a little bit harder. And the students are very, very engaged and interested. I absolutely love teaching. I think it's hardest part of my job because you're sitting there in front of 40 or 50 students, and you're working on presenting an idea. And you get feedback in real time because you can look at their faces, you can see if they're engaged, you can see if they're interested, if you're doing a good job or not. It's very obvious in real time as you're doing it. I very much enjoy it. And I only teach undergraduate courses because I love undergraduate students. I mean, I love graduate students too, but teaching undergraduates is fun.

INTERVIEWER: Interesting. It just seems like you have so much on your plate. You're running the lab, and you have teaching, and I'm sure you do a ton of grant writing. I was just wondering if you could describe a typical day for me.

BELCHER: I don't think any days are typical. No two days are the same. There's all the things that you mentioned. There's grant writing and all kinds of meetings about new ideas, and there's grant reports, there's my favorite part of the day, which is just going in and talking to the students in my lab, which I would do all day long if I had enough time to do it. Looking over their shoulders, see what the data is doing today, and where directions are going. There's preparing for lecture and teaching, and then there's other kinds of things like outreach and being on scientific boards and things like that. And then I also founded two companies, and so there's boards for companies as well.

INTERVIEWER: Do you sleep? I just don't understand.

BELCHER: Well, I slept a lot more before my one-year-old, he doesn't sleep that much. It's all about having great people to work with. And I don't to all of this myself, by any means. I have great support, great colleagues. The students do help me with the grant reports and grant proposals, and it's a team effort. And I think a lot of times, it's this is Angela Belcher's lab and she's done all this. And I'm the head of a lab, but the hard work is really done by the people in my lab. And knowing how to hire the people or get the people together that work well together that have the good scientific ideas and can do the research, but also help with new ideas and pushing the lab forward and writing about them. And then there's writing papers and things as well. It's kind of hard because I don't really have a typical day.

INTERVIEWER: Is there anything since you've come here that you could describe as an MIT moment that really captures the spirit of the incident or just something you say, oh gosh, that's so MIT.

BELCHER: I should have thought about that one in advance. Maybe I'll think about that and come back to it because there's just so much that is MIT. I feel completely surrounded by-- one of the things that I love is that I was walking to get something to eat. And just the conversations that you hear going around in terms of, well, I was working on this cell line and this gene, or whatever it is. It's just surrounding you and it's the enthusiasm and the excitement. And you're kind of peeking and listening because what they're talking about is really interesting. I think that is very, very MIT. That no matter what you're doing, standing, going somewhere, there's some exciting science happening around. I'd say that's more just typical day-to-day and it gets you really, really excited. Or when you walk around and you see student competitions where students are building things or the robotics that they do, and the students are cheering or getting excited about something. I think that is very MIT to me as well.

I don't know, when President Obama came, that was pretty exciting. And that's one of the things that I think about, that when I'm doing something exciting like that, that you think, this is very MIT. That you have people that are important in policy-making, important in the country, that are so interested in what we're doing and what's coming out of MIT. And they believe in us, that we can change the world. And to me, that's very MIT. And that's an exciting place to be.

INTERVIEWER: What was it like to meet Obama? Was there anything about it that surprised you?

BELCHER: I think what it was is that he's a very smart guy. And that's not surprising, but it's the kind of questions and interaction you have in real time that you know are real, they're not staged. Unless he really studied my research, which I doubt he did, had time to do, his questions were just so on the mark. And he seemed very engaged and very interested and excited. I think they actually had to kind of push him on because he wanted to stay and ask more questions. So that was one.

And also just how he puts someone at ease when he walks in. You hear about those kind of people, who walk into a room and put people at ease. I haven't met that many of those people, but you wouldn't expect it from the president of the United States. But I remember being a little bit nervous-- not about meeting the president, but meeting the president representing MIT, because I didn't want to mess up-- and my collaborator and friend, Paula Hammond, she and I were together and he walked in and just put us completely at ease. And it was just like talking to a friend about the research that we were doing. It was just a really smart person.

INTERVIEWER: So would you mind telling me the story about the periodic table?

BELCHER: So I had these periodic tables made for the incoming freshman class that are the periodic table and the elements, it says, welcome to MIT, now you're in your element. And the other side are the amino acids with their structure and the pH at which different things occur. And I had them made because I'm always looking at the periodic table and the amino acids. And it's kind of funny, as we talked about before, when I came to MIT it was almost like this huge relief because I found my home, I found a place where I really fit in. And so when I made the cards I said, now you're in your element because of the pun in it, but also because that's the way I completely found that I really fit in once I got here. And I thought there's probably a lot of other people that once they get here, they realize this is it, that they really fit in.

And so I give them out a lot. I give them out when I give lectures, I give them out at elementary schools and science fair competitions and a lot of people. And so when the president came, I said, I'm going to give him a periodic table. And I talked to my husband the night before, I said, how do I give the president a periodic table. And by the way, here's a periodic table. When is the right moment that that comes up in your life? And so I was really nervous, I think I had it in my pocket. And so I kind of worked through different scenarios that night when I was falling asleep the night before. And so I decided to say something like, I wanted to give you a periodic table in case you're ever in a bind and need to calculate molecular weight. And he smiled, and he took it and he said, I'll look at it periodically. He has that kind of wit, he really got it.

I was happy that I didn't look completely silly doing it. So then later when he was giving his talk at MIT on clean energy and he pulled it out, and so we have a picture of that in my office where he's holding it. And it was in the news. And when I go around and speak to kids in elementary schools and high schools and things, I always give them the periodic table. It's the same one the president carries. I know he carried it for one day, I doubt he carries it now. But then the kids, they just go nuts because they're excited about having a periodic table anyway, but having the same one the president has, it kind of elevates it for them.

It's kind of this dual experience of it was pretty neat to be able to give him that and he appreciated it. At the same time, I think getting kids excited about it, giving them that extra boost from someone like that having the same table they have it, it seems fun.

INTERVIEWER: I know you have-- in the past, at least-- given a lot of talks to middle school and younger students. Do you still do that, and why or how do you do that?

BELCHER: I still do it. I have two small children myself now, so my time is not as flexible as it once was. But I still try to do it. Whenever I'm invited locally, I also speak quite a bit in the MIT Museum and the Boston Museum of Science. So I am involved that way, whenever they ask me do something, I do. And whenever I'm asked from the public to give a talk, locally I do. I used to travel around and do it more, but it's gotten more difficult. Right now I'm working with some other faculty, we're thinking about creative ways of having a larger impact locally in our area and we've come up with some ideas that we're pretty excited about. But we'll see what comes up over the next couple of months.

INTERVIEWER: I was reading an essay by Nancy Hopkins and she wrote that when she came to MIT 35 years ago, her sense was that if she wanted to succeed in science she couldn't get married and couldn't have children. Why do you think she would have said that about science 40 years ago, and what has changed since then?

BELCHER: I think that that was definitely not an unrealistic thing to say at all. She might have had more insight than I did, because this is an all-consuming job. Being a professor, being a professor of a lab, and then-- especially in a place like MIT where expectations are very, very high, not only from MIT but of yourself. You don't get here if you don't have very high expectations of yourself and your work and your teaching.

I just went into it thinking I've always wanted to be a mom, and I went into it thinking that I was going to do both. And I didn't know I was going to succeed in both, but I was definitely going to give it a try. And I think that the timing worked out for me that I was full professor about the same time that my first child was born. And that had less pressure on me because I wasn't having to go through the tenure process. So I think that starting thinking about going through the tenure process and having one or two small children at the same time would be extremely-- and I've seen women do it and succeed-- it seems extremely difficult. I don't think that that's a function of where you are, it's a function of how many hours you have in a day. And your lab always needs you, your students always need you, and your kids always need you. And it's how to split up that time. So I understand completely where that comes from.

I didn't think much about it. I think I was always worried about it. From the time I was a graduate student, I was worried about it. How am I going to do both? And as a young faculty member, I think I was worried about how am I going to be able to accomplish both? I think that time will tell how successful I have been at it, but I think that the way things are set up at MIT now has really helped a lot. So the child care, I can't say enough about having the child care on campus, where I have a one-year-old there now and a five-year-old. And being able to go back and forth between my office and child care when I have time to have lunch with my kids and play with my kids and teach in their class means absolutely everything to me.

I think that is completely part of what my success has been, is having a place where I completely trust the well-being of my small children and then get to come back and forth during the day and be with them and be a mom and then go back and go to my meetings and go back and forth. So I'm just one building away. And to me, that has been a part of why I've been successful at doing both at the same time.

INTERVIEWER: I'm sure you have male colleagues who are the same age and also have small children. Do you find that they have the same worries or concerns that you have, or do you think mothers have--

BELCHER: Well, I don't think I can say as much about my male colleagues, but I don't know what being a dad is like, but being a mom and a dad is different. And I just know between my husband and I, we have very different jobs, different roles. And I am a worrier, I think about everything. And my husband doesn't. He kind of thinks, everything will work out. I think maybe everything will work out because I'm taking care of it.

So I'm not sure. I did make a comment to a colleague once where when my son was about one years old, I said, I just went for 15 minutes without thinking about my son. And that was really strange. My kids are always on my brain first. I'm going around doing something, I'm writing my grant proposal, or-- not as much when I'm teaching, because when you're teaching, you're really all-consumed with teaching. But I think okay, now the kids are having a snack, now the kids are having lunch, I wonder if they had a good nap. And that never shuts off, it's always at the front of my brain. So it is interesting. But I've learned how to do both at the same time.

The hard part is traveling. When I have to go for a grant review or I have to give a lecture that I promised I'd give two years in advance, the hard part is juggling with that. That's been the biggest issue, because my husband work in very-- he's in Wooster and I'm in Cambridge, so it's a far distance apart. It's one of those things that will be interesting to see how it works over time. On an individual day, things are absolutely crazy but we're all happy. I have what I love most, which is I love being a scientist and I love being a mom and I can do both at the same time. Overall, it feels great, it feels successful. But it really is having the support. And the support in this case really comes from having my kids right on campus, and having a place I really trust to help take care of them.

INTERVIEWER: Do you think that becoming a mother has changed your science at all, or has made you think about things in a different way?

BELCHER: You know, it's kind of funny. It's changed me as a person a lot. I think it's made me a more patient person and a kinder person and I'm definitely a more reasonable person, because you have to look through the eyes of other people. But in terms of the science, maybe it's made me break things down more. My oldest is very interested in science. I wanted him to be good at something that I wasn't good at, that was my first choice. But then he's just a science engineering guy. And I'll be working on a lecture and he'll say, what are you doing? I say, well I'm going to be doing this enzyme reaction tomorrow. And he wants me to break it down and teach it to him. And so I'll break it down-- this is since he was three years old-- this is an enzyme, this is how it works, this is how it does, same with solar cells. Everything we do, everything I do, my now five-year-old wants me to break it down and explain to him.

And I think that what it's done is it's definitely made me a better outreach teacher because now I know how to teach solar cells to three-, four-, or five-year-olds-- or enzymes. But I think it actually helps me think about how to break things down a little bit differently. The other aspect that it might have improved is not having to be perfect. Because when you have all these things going on, there's just no time for perfection. And you have to make decisions about what you want to be perfect in and not everything can. And I think that's been a valuable lesson. And time management, whatever that is.

INTERVIEWER: And you mentioned that your five-year-old is already a science, math kid. Will you encourage your kids to go into science?

BELCHER: You have to wait to see what the personality of the child was. People always think this is strange when I say this, but when my son was growing-- there's a big difference for me between a baby and a toddler, in terms of interactions with them. With babies you have to take care of them. You have to make sure they're happy and warm and have food. And then when my son got to be about 18 months old, maybe it was just about a year, he really started developing a personality and had really different needs. I had to learn the best way to interact with him. And it was kind of interesting because he likes putting things together. And so I would get all kinds of science kits and I'd bring them home and we'd build-- these are science kids that would be eight and up to 10 and up-- we'd build things together. From the time he could walk, we'd work on building things together and I'd talk to him and explain things about them.

I guess maybe in a way I pushed him into science in that way, but I couldn't teach music because I don't know music, and I couldn't teach him art because I don't know art. I kind of worked with him based on what I knew. And he loved it and is excited about it. And he's always designing his own machines or doing his own experiments. And I'm not sure if he got that love of science genetically or environmentally or what. But I think he sees how much both my husband and I love our jobs. And that's one thing that we try to show our kids, is not only do we try to show them a strong work ethic-- which is very important to both of us-- but how much joy we get out of what we do. And I think he definitely picks up on that. And do I want him to be a scientist? I think that people have an innate ability, things that they're passionate about, things that they love, and that's what they should do. And I've always told him. I said, I don't care if you're a scientist or if you're a musician, whatever it is that you love most, that's what you should follow. And I believe that completely. I just want him to be a nice person and a hard worker.

INTERVIEWER: So I wanted to ask you to just describe your current work, the big picture.

BELCHER: The main thing that my group does is we try to understand how nature makes materials, how biology makes inorganic materials, mostly. And what can we borrow from that? And so the idea is based on about 500 million years ago, organisms in the ocean started making hard materials. And the example that we talked about were abalone shells. And so abalone are a marine gastropod, they're a snail. But they make really exquisite inorganic materials which are basically calcium carbonate, basically chalk. But if you've ever held an abalone shell, you can see how tough and how strong the structure is, but at the same time if you look inside, you can see how beautiful the structure is, the mother of pearl structure of the shell.

Well, all of those properties-- the beautiful structure, the hardness, the toughness-- comes from how this organism manufactures this inorganic composite material, this abalone shell. And the way that they did it was they have cells-- it's an organism, they have cells-- that pump out proteins. And these proteins can grab on to ions from solution from its environment, the ocean. They take calcium and they take carbonate out of the environment, and they sort to build up these really exquisite layer-by-layer structures of calcium carbonate. So if you take that and you compare it to chalk, which is the exact same chemical makeup, calcium and carbonate, it's very, very different. So the chalk is made on a much larger scale, the little crystals that make them up are made on a much larger scale.

But also that whole composite inorganic material that make up an abalone shell is two percent of its total mass is protein. Two percent percent of it is biological, 98 percent of it is inorganic. But yet that 2 percent is magical, it has a big impact on the quality of the material. And so organisms, over about a 50 million year time span, learned how to build really exquisite structures in the ocean. Examples are abalone shells, diatoms make beautiful glasseous structures, micron to a little bit larger size structures. And there's iron oxides, there's iron-based materials inside of bacteria that make little single-domain magnets that are used for navigation. And there's a couple other kinds of materials. And of course, there's the example of us, which is calcium phosphate for our bones.

Looking at that, you say wow, biology did such a great job in taking what it had in its environment and making materials that have really interesting properties. But why couldn't they have done more? And it goes back to the idea of the periodic table, where organisms did a great job with what they had in their environment. They had calcium in their environment, they had phosphate in their environment, they had iron in their environment, and they had silicon in their environment. those structures, From those elements, they built really exquisite structures. And so that's what I worked on as a graduate student, was understanding the process of how that works.

And when I started my own independent lab, I said, well what about the rest of the periodic table? So abalone shells are great for abalones, but not that useful to me. What can we do to take those same principles that evolved over 50 million years to work on something that can be more useful as a product, more useful to me? And so what I did was developed, of course with my students, this process of looking for proteins that control different elements on the periodic table to make interesting electronic materials, or materials for energy or materials for cancer.

And the idea is that in the abalone shell, there's a protein that's involved in nucleating or forming the structure of calcium carbonate that is very negatively charged. It has negative charged amino acids out of it. And those negative charge amino acids actually put down calcium, and put down calcium in one layer then calcium carbonate. So I said, what we need to do is find proteins that can control semiconductors, we need to find proteins that can control magnetic materials that, through evolution, biology hasn't had the opportunity to work with. How do you do that? 50 million years is a long time. So we use biology, and we use a combination of combatorial chemistry-- doing lots of combinations at once-- in evolution to try to find the right protein sequence that can build a battery, or that can build a solar cell. And that's done not by manipulating proteins but by manipulating the DNA that codes for those proteins.

And so what we developed is how can you look for, how can you fish out a possibility of a protein to build control nucleation, size, placement of an inorganic material that will make a better battery. Let's use that as an example. And we did it by taking a virus, it's a virus called M13 bacteriophage, it's a virus that infects bacteria. It's only infectious to bacteria, it's a bacteriophage, meaning a bacteria eater. And what we did, this virus is really beautiful. It has a single single stranded DNA, and the single stranded DNA codes for the proteins that make up its structure. It's a long, skinny virus. It's about one micron in length and about six nanometers in diameter. And it has all the DNA sequences to make its beautiful protein coat.

And it's single stranded DNA, so you can take the single stranded DNA and open it up and put a random sequence of DNA and basically close it back up. And by doing that, by putting this random DNA sequence in it, it codes for a random peptide sequence or short protein sequence on the coat of the virus. And so what that allows us to do if we do that a billion times, open it up, put a random sequence in, you could have a billion different viruses that are all genetically similar, but they differ based on a small amino acid sequence. OK, that's the key. What we're going to do is we're going to use a billion different peptide sequences all attached to a billion viruses to look for the peptide sequence or the short protein sequence that can bind a semiconductor material and bring it together. That can bind material for batteries and bring it together.

So why would we want to do this? There are a couple of different reasons. One, going back to the example of how organisms in the ocean made materials. They do it under ocean temperatures and pressures, they don't use organic solvents, they don't use toxic chemicals, and they don't add toxic chemicals back into the environment. Wow, what a manufacturing idea. Let's use non-toxic materials and what's available in our environment, and not leave anything bad back. And so that was our manufacturing plan that we decided to go with. So let's use biology to do that. And so that's been the focus of our group.

The other thing, going back again and taking a lesson from an abalone shell besides the fact that it's clean manufacturing, is that they build things based on the nano scale. And that's what actually helps give the shell its toughness and its strong structure. It's based on the fact that the little inorganic materials or the calcium carbonates, it's built up around the nanoscale. If you take an abalone shell and you fracture it, what you see is that it's made out of these little plates. And these plates actually intercalate like this, they look like a brick wall-like structure. And you're like, of course, if I'm going to build a structure, I'm not going to build a structure like this. I'm going to build this intercalating structure that makes this brick wall-like structure.

Well, what's fascinating is that the animals built that structure up and they have it intercalate just in the best way to build this really tough structure, and it's nanoscaled. So we work at the interface between biology and nanoscience. You say, nano is very small, nano's a big topic right now. Why is nano important? Is nano important because it's small? And I'd say no. You have your nano iPods and things like that, and nano cars. It's a great word, people are excited about it because it's small, but that's not the reason why it's really so interesting. Having things are small can be good, but you have to scale it to a larger scale to be able to use it. So if I have a really small computer, it's going to be hard for me to type on.

So we need to figure out how to take advantage of nano components but than scale it to something that's useful for us. And the thing about nano is that when you think about collections of atoms are put together in a very precise way, properties can change, the properties of a small collection of atoms compared to bulk. The electronic properties can change, the magnetic properties can change, the optical properties can change and become very, very tunable. And that's the exciting part about it. The exciting part is that small is great because the individual atoms that make it up, they change their properties, they change when they're in a small cluster together. And that's actually what can make a better battery. That's what can add some important aspects to a solar cell or make an important new probe for cancer, is the fact that you can start to tweak and you can start to change some of these properties of materials and put them together in new ways. And that's what my group is focused on. And that's what we're pretty good. We're pretty good at putting collections of small things together in new ways.

And one of the things that you think about-- and take batteries as an example. We work in rechargeable batteries, lithium ion batteries. And we've worked on using biology to make electrodes for batteries. In these batteries, you're going to have two electrodes, a positive and a negative electrode, and you're going to have some lithium ions in between. And the lithium ions are going to interact with one electrode and interact with the other electrode. So the part that's going across this way is ionic connectivity, but you have to get electrons in and out also. So you have to have a material that actually is good it ionic connectivity and electrical connectivity. So you go to the periodic table and you say, okay, what here is going to be good at both? And sometimes it's really hard to find those materials that have all the properties-- whatever property it is-- that is good at this and this and this.

And that's where the biology comes into place in terms of us, because what we can do is we can have biology act as a soft template to grow a good electronic material right next to a good ionic conducting material, maybe next to a good optical material. Because what happens is because the proteins that are binding and pulling these materials out of solution are soft and you can pull them right next which to each other. And you can genetically code that you want a good electrically conducting material and a good ionically conducting material side by side so that those can communicate to have a new feature.

And so that's what we did our battery, the battery that went to the White House, for example. We engineered a virus to grab on one end of it good carbon nanotubes, collections of carbon nanotubes, which are good conducting materials. And we engineered the rest of the virus along the length of it to nucleate a good ionically conducting material for a battery. So now when we took these viruses, we had these viruses that were covered in this iron phosphate material, a battery electrode material, and we had the little fingers of the virus reaching and grabbing onto individual carbon nanotubes. So now when you put them together, you had a network-- it's called a percolating network-- of good ionic conducting materials and good electrical conducting materials-- and boosted the performance of the materials. So that's what we do and in lots of different instances.

We just had a paper out on solar a month ago, maybe, where we engineered viruses to pick up single walled carbon nanotubes and line them up along the surface of the virus, and we gave them a second gene to grow a good material for solar cells, titanium that's around the carbon nanotubes. And what it did was it gave a good pathway for electrons to basically travel along this virus-based structure we made and get to where they needed to go. So we increased the solar cell by two percent, we added two percent efficiency just by changing the electron path through this combination of viral engineering to make a material in a different way.

INTERVIEWER: Now when you describe it-- and you do such a good job describing it, it all seems like a very clear and obvious idea to use biology this way-- but it seems like it's only really this field of, I don't know what you call it, directed evolution, has really taken off in the last decade or two. Are there new tools available? Is it just you?

BELCHER: There's a lot of people that are better in directed evolution than I am. But what we do that's different is we really put the idea of evolution and material science together. There's people that do a really fantastic job of engineering what biology already does to change and become better, faster than it would through waiting to have it through evolution. The idea that we're at least partially responsible to bring to the table was, okay, let's engineer biology to work with inorganic materials, materials that would never have experience through the natural selection process.

And when I first started talking about that, when I first wrote my first grant proposal, most people called me insane, actually. I wish I still had it. It was so traumatic to me, I think I threw it away. You've been in your new office for a month and you're a professor now and people are calling you insane. So I'll never know who that person was, but that was pretty hard. But I managed to keep pushing forward. But now it's not insane anymore. Now it's actually a pretty reasonable approach of how to do it.

I remember the day I thought of it. It was when I was still a graduate student. And I remember it very clearly because I was in my office, I had this great office overlooking the ocean. And I had this giant periodic table pretty high up, I had to put it pretty high up, just based on how my desk was laid out. And I was standing on top of my desk looking up at the periodic table, and that's when I really came up with the idea of trying to expand the elements that biology could work with. and I didn't have an idea how to do it yet, but I knew that that's what I wanted to do.

INTERVIEWER: Was there something about having the view of the ocean, and thinking, the abalone did this with only x elements, and if they had these elements.

BELCHER: It definitely was. I was very fortunate to work on basic science ideas as a graduate student, but always be exposed to the idea that we were trying to use basic science to solve problems, which could be engineering problems. And I did basic science as a graduate student, studied proteins that controlled calcium carbonate and tried to see which proteins controlled which different crystal structure of calcium carbonate. That's what my PhD was on.

But I knew that ultimately I wanted to go towards an application. And as a graduate student, I started playing around with the natural proteins that I'd worked on isolating, and giving them different elements to work with. And I saw that these proteins could also affect the nucleation of things that were structurally very, very similar to calcium carbonate. Unfortunately, nothing that was structurally similar to calcium carbonate which they could affect was interesting technologically. And so that was a joy at the same time. It was like, wow, it worked with calcium carbonate and worked with these other materials as well, but what about this? This is the part of the periodic table I want to work with. How do I get there? And so I went through a process of thinking about how do you get from where I am to new proteins that can work with anything I want on the periodic table?

And a lot of people think that was kind of a big jump. But in my mind, it was a logical progression. I didn't know how it was going to get there, but I worked through a lot of ideas that were not as good. I worked through them in my mind and on paper, and what is practical for how to get there.

INTERVIEWER: Since you came up with his idea in the past 15, 20 years it seems like there's been a lot more meeting between biology and material science and engineering. And I was wondering if you had any ideas why that has happened.

BELCHER: There's been so much progress in biology and molecular biology over that time period that you've talked about. There's been a revolution in biology from the technical side, in terms of inexpensive DNA. And when I first started thinking about this, it was hard to make a library. But what I talked about in terms of cutting and pasting the DNA, it's called making a library of genetic possibilities. People do their whole PhDs on making libraries.

INTERVIEWER: Yeah, you were just saying there was one PCR machine in that whole lab.

BELCHER: Yeah, in the whole building. I think it's a combination of the growth of this field that makes it accessible for people who aren't experts in it. When I first started thinking about how to make this connection through material science that I was interested in and new proteins, I knew that one possibility was going to be to have to make a library. But I certainly didn't want to make a library because I didn't have the skill-- well, I could have done it, but it would have taken a long time. And about the same time, these libraries started becoming commercially available. And so there is that aspect, and I think it's incredibly important that the biology and the technology has grown up so much that it's much more affordable. And people like me who are not experts can enter a field or use the tools from that field.

I think that's come up with a lot of ways. If you think about atomic force microscopes, I was in an atomic force microscope lab as an undergraduate physics lab, where they built all the instruments. And they weren't user interface friendly. And right now we have two-- an elementary school and a middle school teacher in my lab this summer, and they're learning atomic force microscopy and they're running it themselves. And part of it is that they're motivated to do it, but part of it is the tools are such that they're much more user friendly now. And I think that actually is key.

But I think there's been a shift in thinking too. Because when I first decided to switch from creative studies-- which my emphasis was in biology so it was a biology, biochemistry background into solid state inorganic materials-- I was given a hard time about that. And I remember going in and taking the entrance test and scoring the lowest of anyone in my class on it because I'd never had the courses. I figured, how hard can it be to learn this material? I just haven't learned it yet, it doesn't mean I can't learn it. It was a little discouraging.

But I think there's been a shift towards the idea of-- it's a cultural change in the multi-disciplinary approach. And I don't know what that has come from. I think it's from watching very valuable-- maybe it's funding, partially funding-- but I think it's also very valuable research has come out at these interfaces. And then I think it's also, in the case of the biology materials interface, it's also been that the technology has become much more advanced and people been able to use it. Like me, I wouldn't have done this if I would have to start by building my own libraries. Now we do that all the time in my lab, but it would have been a really hard place for a solid state inorganic chemist to start their research lab in building libraries. So there's that.

I think that students are very excited now about being in the interdisciplinary approach. The young people I meet, whether from high school or from college, are interested in engineering, making things. And making things that have an impact in the world. A lot of that is not only for the high technology end of society, but also that has an impact on people's lives in undeveloped countries and things like that. So you have to think about how to make something effective and how to it make it inexpensive. So there's a lot of practical engineering going on, which I'm pretty excited about.

I always go back to the abalone. The abalone doesn't say, I'm a biologist, I'm going to build a shell like a biologist. It takes what's in its environment and builds the most-- what's the most effective way to build the best structure possible? And that's kind of how we think in my lab. We think we want to build a better solar cell, we want to build a better battery or catalyst or whatever it is that we're working on. We just want to to figure out a way to build a very good device and do it in a way that's environmentally friendly. And the tools of actually how to get there are less important to us. So I'm hoping it's a shift in the idea of wanting to make practical materials, trying to make things that impact our lives and impact the environment.

INTERVIEWER: It's interesting, I was going to ask you next if you consider yourself mostly a chemist or a nanotechnologist or a biologist. But I wonder if you just think of yourself as an inventor.

BELCHER: I think of myself as an engineer, which is kind of strange because I don't actually have any engineering degrees. But up until a couple years ago, I'd say I always considered myself a chemist because I like to think about structures and bonds. But now I just consider myself-- I'm not just, I think I'd consider myself an engineer because what we're actually interested in is finding ways to make things in a way that's high quality and useful. An inventor, I know I said earlier that I set out to be an inventor. It's very strange, I have no idea where that came from. I do remember being in the work bench in Houston and no air conditioning in the summer. And it's one of those kinds of things that's strange, because it was a strong driving force in me to be an inventor. And I think it wasn't until I was actually in graduate school and a professor that I really realized it came full circle and I was, in fact, inventing things.

INTERVIEWER: You talked about this a little bit earlier, about how your lab seems to have its fingers in a lot of different projects-- carbons, sequestration, batteries, and solar cells-- they all come from the same origin. But I was wondering how do you decide what types of problems to work on? And what types of things do you turn down?

BELCHER: We only work on things we think we can have an impact in. And we will do some experiments to see if we can have an impact in the field before we commit to working on it. We are really a materials group, we build materials, we use biology to build materials. And once we've figured out a new material, a new way of processing something, then we-- and I say we because it really is my students by themselves, my students and I together, kind of scoping out the possibilities of where we think that this kind of material can have an impact.

And that's kind of where we guess. We don't look at anything that we don't think we can do something pretty good in. We don't look at anything that's not an environmentally friendly approach. That's the main things. We only work on things we think can get funded as well. But that usually is a pretty good interface.

INTERVIEWER: Is there anything recently that you've passed on or tried or looked at and said, no, that's not for us or not for us right now?

BELCHER: People have tried to get me to work in some areas over the years that I've turned down or put on the back burner for a while because I wasn't sure if there was something that we had to contribute to it. Cancer is one. It was Bob Langer here at MIT who asked me to work on cancer over five years ago. And I never really wanted to work in the medical area because I didn't really know what we could bring that was important. And cancer is such a complicated problem, and it's such an important problem that I didn't want to work on it unless I thought we had something to contribute. When Bob Langer asked me to join this proposal he was putting together, I've never figured out how to say no to Bob, that's really how I got into this.

Talking to him, we were going to focus on making materials. And the materials that we first started working on, we were able to make materials, but they didn't really work out. They didn't really work in the kind of applications we were looking at. And we kept going back to the board and making modifications to it. And where we are now, the things we're interested in now in cancer and diagnostics is very different than what we originally put forward when we started talking to Bob Langer about it. I'm pretty happy, where there's been a lot of trial and error to see if we can come in and make a difference. and I'm pretty excited about where we are right now. We had to learn everything, I knew nothing about cancer, nothing about human cells. And we have human cell culture in the lab, there's just been a lot that we've had to learn about. And it's been very, very fun. It's been somewhat overwhelming, but I'm finally starting to feel good about where we are, that we have some ideas that could have impact. And so that one example.

The other example is CO2, sequestration and storage, people have asked me to work in that for quite a while. And I've always said, oh, that's another problem. It's too big. The problem is very, very big. And I try to think about if there's something interesting that we can do. We've had a project for about three years now where we've looked at converting the CO2 into building supplies. And we went into it because we were very enthusiastic, thinking okay, we can. We did some calculations, and I did some initial experiments and thought, yeah, we can make an impact in this.

And the project is just getting to its endpoints. It was a three year project. And what we found is that we can make an impact, that we can take CO2 and make it into building supplies. But what we can't do is take all the CO2 made from a particular power plant and store it as a way that can be stable on the order of geologic time, which is what I was interested in. But what we can do is take a small amount, store it on the geologic time scale, and make it useful and replace other processes that would actually increase CO2 in the environment. So that's another example.

INTERVIEWER: Tell me a little more about the cancer work, or just about your involvement with the Koch Institute. You moved into the new Building 6 months ago. How is that?

BELCHER: Fantastic. I was really reluctant to move, I didn't want to move.

INTERVIEWER: I'm seeing a trend.

BELCHER: I didn't want to move because I really liked the space that I was in. I had a pretty nice space, and I liked the way my students were set up. I didn't have enough space, but we ended up to be a little bit isolated where we were in my original space. I said okay, we're a little bit isolated. We're just going to become isolated. We're going to be self-supportive. We're going to have everything we need to have to maintain a good group. And so now we have the opportunity to move into the new building, and it was just a little bit of a move that was-- I was a little nervous about shutting the lab down and opening it back up again. And then we were going to go from being this kind of isolated group to being a very integrated group. And that's my training, is integrated group. I kind of got used to-- it wasn't that we weren't collaborating, but we were pretty self sufficient in a lot of ways.

I was the last person to move my lab over there because I also had an infant at the time. But I absolutely love it. And everything I was worried about is what I love most. I love how open the labs are, I love the fact that I'm in an office suite with no other engineers. Either the planned conversations, the bump-in kind of conversations we have, or overhearing conversations is very, very interesting. Because what it's doing is it's immersing me in-- it's I can make a material, but I don't know what's important. But learning what's important from a perspective of people in the cancer field makes what I do so much easier and more relevant because now I can design materials not just to design materials, but design them for trying to solve problems that are real problems. Not just problems that I think are important. So that part is really great.

And then the building is beautiful. The equipment is amazing. There's just nothing that's not great about it. It was great.

INTERVIEWER: You've talked a lot about some of the advantages of using natural processes to design new materials. Are there any disadvantages?

BELCHER: There could be disadvantages. There's probably disadvantages to most processes. So the things that we run into is in every situation where we've really put a lot of effort and decided it's a direction we want to go in, we've been able to make a pretty substantial increase in the properties of the device or materials that we're looking at. Batteries, solar cells, catalysts. Anything that we've really gone down the path, we've been able to show improvement in. The kind of things that have been a disadvantage is you start thinking about scale. You start thinking about scale of CO_2 sequestration. There's a huge scale. You start thinking about scale of solar. That's a big scale. Or making enough battery to not only run your car but millions of people's cars.

So we've approached that in a couple of different ways. So one of the things we did recently in our solar paper is that we took process of solar cells-- we took a kind of solar cells called dye-sensitized solar cells that are a solution process that can be role-to-role process as well, so inexpensive solar cells. In this case, what we found is that 0.1 percent biology can have a huge impact on the overall solar cell. And so just point one percent of our material embedded in an already existing manufacturing process can boost efficiency by two percent in our test cells in the lab.

And this is pretty exciting to us because I'm all about biology. Biology does everything. But practically stepping back and say, what if you invented a way where a little bit of biology went a very long way? That can be important in terms of scale. And so now I don't have to change a process for how already existing solar cells are made. And I don't have to worry about making enough virus to cover every rooftop in the country. I only have to figure out how to make a small amount to have a big impact.

We started thinking about things in that way. In terms of the basic science or manufacturing things in a lab, I would say that there's not disadvantages that I can think about. Whenever you go from a prototype device to medium-sized scale to large scale production for the world, there's all kinds of things that can pop up in terms of how do you scale things. And so we've been very effective in making prototypes in the lab, and in some of the things that we're looking at now for smaller scale devices for batteries, as well as larger devices with 0.1 percent biology we're going to the medium-sized prototypes to test them right now. So that's pretty exciting.

And in terms of one of my companies, Siluria Technology that I founded, the idea that the company had was that to take advantage of how well biology makes new materials and new processes-- this is a company that works in catalysis, actually, for taking methane from natural gas and making it into ethylene, which can go to make all kinds of products. From plastics, to a lot of things used in our everyday life to liquid fuels for vehicles. What they did in that case was use a little bit of biology to make a material that's a catalyst that can be used over and over and over again and to take a material that's not very valuable-- methane-- and make very valuable products out of it. So in that case, again, it's picking the particular kind of application.

INTERVIEWER: Tell me a little bit about your startups and your involvement in those, and what's that been like for you.

BELCHER: It's been a great experience. It's been a big learning experience. I founded two companies: Cambrios Technologies, which is an electronics materials company, and Siluria Technologies, which is a natural gas to products company. Cambrios was founded in 2002, and it was built on the idea of friendly processing of materials. And in Cambrios's case, there's actually no biology in the product, but the ideas were all based on environmentally friendly processing solution, base processing of materials. And we have products that are out now and smartphones that you can buy. I actually have one, I carry one myself, in my backpack.

And what Cambrios did was work on making transparent conducting materials for-- the main application right now is touch screens. You probably have a touch screen device yourself. The electrode material is transparent, that allows you to effectively use the touch screen display. And most of transparent conductors right now are based on indium tin oxide, which is a material that's becoming more rare. And there's also geopolitical implications of this material. And what Cambrios did was figure out a way to replace indium tin oxide with a more earth-abundant material that's all solution-based process. We have a manufacturing facility in California, and we can make enough transport conductor for the whole world, in terms of touch screens, in one smaller sized facility. And that's all based on thinking of a different way of processing material so there's no multimillion, multibillion dollar fabrication process. It's all grown.

INTERVIEWER: Have there been any surprises for you being in the world of business?

BELCHER: Oh, it's all surprises. It's very different than academic life. So I was a founder of Cambrios and a scientific adviser. And I'm still on the board of directors, but running the company as is done by business people with a lot more experience in business. And we have over 40 scientists and engineers working in that company now, making devices and producing materials. It's very, very different from running an academic lab. For me, there's not very many parallels. It's one thing that's so much fun about that and my second company, Siluria. I understand all the arguments now for-- I understood it before, but I understand it so much more now-- all the arguments for more small businesses in the United States because once you get a technology into a small company, it moves so fast.

Really smart people are attracted to work in small start up companies and you have 20, 30, 40 really smart people all really pushing and working on-- in the case of materials-- of building the technology that needs to meet all kinds of specifications. It has to get there quickly, it has to get there economically, it has to have performance. It's a winning combination to watch these really bright scientists and engineers that we have so focused on making this happen.

INTERVIEWER: And is that the biggest difference with academia, the speed?

BELCHER: No, the difference is in-- well, I wouldn't say it's the speed, it's just the approach to things. And this is only from my perspective, is that we're trying to solve problems. We're thinking about interesting ideas, but we're not trying to make products in the lab. We're trying to develop interesting materials for interesting processes. But we're not under the kinds of deadlines and performance specs that you are in a small company trying to make it in today's economic climate.

It's just different. It's very different approaches. And the thing that I love about my job is I get to do both at the same time. And my feet are more firmly planted in the academic because that's my full time job. And I really enjoy the learning process, the process of training students, the process of having the freedom to really try to pull together very different ideas and to build something new.

And then in the other side, in the companies, the technology may be a little bit more advanced, it usually has be a little further along because you're having to push it to some particular spec, in the case of our touch screens or in the case of the second company that I have that's in catalysis. The timelines are shorter, the intensity is very, very high intensity. It's very interesting, it's very fun. It's very fun to see how rapidly they make progress. And it's partly because of the expectations on the different-- I'm not saying that one progress is better than the other, because there are very, very different kinds of progress. But it's fun to have a foot in both.

INTERVIEWER: I wanted to ask you a bit about the MacArthur grant. I understand the whole process is kept secret until you get a phone call. Were you expecting?

BELCHER: I wasn't expecting at all, no. I answered my phone and because so many people-- this sounds pretty funny-- but so many people call me about different things that I kind of developed an answer on my phone that was just kind of, hello, this better be important because I was preparing for a lecture. And I didn't recognize the number, I have no idea why I picked it up. And at first you're going, is this real, kind of thing? I didn't expect it at all.

INTERVIEWER: What did they say?

BELCHER: It was a while ago, it's hard for me to remember.

INTERVIEWER: It was interesting, some of the Nobel Prize winners. It's this set thing. They call at five in the morning, and it's this foreign voice on the phone. Did they call you and say, "Dr. Belcher, we're calling from the MacArthur Foundation?"

BELCHER: Yeah, I think they said that. No, it was completely out of the blue. It never occurred to me. I didn't know the time of the year they call. And I was really focused on getting my lecture together. And I don't know why I answered the phone because I usually don't answer the phone an hour or two before lecture. And it was very surprised. And you can't tell anyone for weeks. I think I told my husband. But it's a secret until there's the announcements. I don't know why they don't tell you if they make you keep it a secret. So I don't think we told-- my husband and I went out to celebrate dinner that night.

INTERVIEWER: Did you go and do your lecture?

BELCHER: Yeah, I went and did my lecture. There's no choice about that. It took a while to sink in. There was a year or two in there that was such a great time because I wanted to go out there, and I became-- I can't remember if I had tenure at the time, I think I had tenure-- I became full professor and I had my first child and it was all around the same time. So it was just a very magical time for me.

As time has gone by, I've realize more how big of an impact it had on my life, which I didn't realize that year, the next year, or the year after. But it gives you some confidence, and it gives you some-- I wouldn't say credibility, really, but some recognition that can be very, very helpful. But the financial aspect and what ended up being most important was actually using that to help pay for child care and things like that. Last year I won the ENI prize in energy, and it's also extra money too. I was like, okay, well the first one helped pay for the first one and the second one helped pay for the second child. So it's been very helpful.

INTERVIEWER: What's it like to be labeled a genius? Like you got the actual genius stamp?

BELCHER: I don't think anyone takes it that seriously. I definitely don't take that aspect that seriously. I think it gets you nice invitations to speak and other possibilities. I think that it's been very fun. The further away I am from it, the more fortunate I feel about the whole experience.

INTERVIEWER: What would you say has been the highlight of your career so far?

BELCHER: The highlight of my career so far has probably been-- what I set out to do was use biology to improve device performance. And I'd say that making our batteries, making the first two papers we had in science on using biology to grow multiple things and improve device performance of batteries was just absolutely huge for me. I always say when I give lectures, this one slide that looks kind of boring, it was the second best day of my life. The first one was when my son one was born. And the second was the day that I saw this data because this data was our first example-- I think it was on batteries-- our first example that a change in the DNA sequence could improve the power performance of a battery.

And that had been everything to me, that DNA sequences were going to code for the improved device performance of something useful in our lives, a battery, a solar cell. And I always say that I've got to change it to top three best day in my life now, was the day that we really showed that a DNA sequence could have this dramatic effect on device performance. That's been the highlight for me.

INTERVIEWER: That must have really validated everything you've done up until then.

BELCHER: I'm not sure if it was validated, because I've always believed in myself. So that has never been an issue. I guess I have days where I don't. But I always felt good about the path that we were on. But that was the dream come true. And it's one of those things where it's like, yes, it's so exciting. My students were excited too, they got a big paper out of it. That was the battery that went to the White House. And so there was a lot of really great things about that. But to me, I followed the string all the way back to okay, this is what we said we were going to do. This comes from the ideas of biology, I followed the strings all the way back to the beginning over that 10, 15 year period time and it was validation. It was like ha, it was like we did it.

And maybe how good I felt about it wasn't-- it was a nice paper, people were excited about it. It wasn't on the same scale as how excited other people were about it, maybe I was more excited. And it's mostly because this was a dream come true for me. This was the dream. But then the next thing it does, you do that, a couple years later you have to readjust your dream, right? I've got to dream bigger. Did that, check that one off the list. I have to dream bigger.

INTERVIEWER: Right, right. Have you had any professional failures or setbacks that you learned from, that had been tough at the time but in the long run ended up being instructive?

BELCHER: Well, it's the work that you think really is good that gets rejected from papers, gets rejected from a journal. That's a learning process. I remember the first couple of rejections, including the person calling me and saying, you have to recalibrate. And the best kind of recalibration is when you take what the reviewers said and you say, yeah, there's some valid points in this. I understand where they're coming from. And you take these valuable points and you-- especially when you're young and you're starting out when you really-- in my case, I really didn't know what I was doing. Restructuring things to make it better. I wouldn't consider those failures, necessarily. I don't ever feel like I've really failed at something. But I've realized I've overreached, and I've learned from when I overreach. Okay, I shouldn't do that. I should make these steps first. I think those are important.

INTERVIEWER: It's interesting that what you're talking about, how a career in science, so much of it is about figuring out those things around the science. It's not just doing the great science, but it's figuring out how to write the papers and run the lab. And it seems like nobody quite necessarily teaches you those things. And I was wondering if you'd talk a little bit about that, about what makes a successful scientist, having all these different characteristics.

BELCHER: Well, I think it's definitely on-the-job training. And I gave a commencement speech a couple years ago, and I addressed this because when you-- I don't remember the title of it, but I think it was, "Be an Expert: a Work in Progress." And I really think that that's true. When you first graduate with your PhD, you're given your degree, you're an expert in the field. And you go off and once you're there for a couple weeks, couple months, you realize you're not really an expert. There's a lot to learn. And I think that that is true, even now that it really is a work in progress, learning from your experiences.

And I remember the first time my first PhD students, you're thinking, okay so I'm in charge of deciding what makes a good dissertation, what makes a good PhD when you might have just finished your PhD two years ago. And learning the expectations of what a good PhD is and the best way to train students. And I think that I had really absolutely fantastic PhD and postdoc mentors. And my postdoc mentor who's been in Boston now is-- not as much in the last couple of years, but definitely in the first six years of my faculty position-- I would call her up and she would give me advice all the time. You're taking this too hard, you need to focus more in this direction. And so I think mentorship is really, really key. And I don't know what kind of mentor I am, exactly, but I do know that I have high expectations of my students and my students are involved in the process from writing papers and writing proposals and revisions of papers and buying equipment, designing equipment. And so I think that they will go out in the world with a lot of experience in how to set up a lab.

INTERVIEWER: It seems like most scientists get into science because they want to do science. And I saw you talk somewhere saying that you actually get like 30 minutes a day to think about science. Was that an exaggeration?

BELCHER: No, it's not an exaggeration. It's not an exaggeration. What I love to do is think. I feel like it's such a luxury to get to think and. And I feel like I'm doing something wrong because I'm trying to clear out my schedule so I can think. Because that's actually what I do best. That's what my skill is, is creative thinking. I was a good experimentalist, I'm not anymore. My students have been much better for me from a very, very long time. I'm a good teacher, and there are certain things that I'm good at, but what I love most is thinking. And I love thinking about ideas and to me, it's been much better than dessert. That's what I'd love to do. And my assistant will help me clear time out so I can think. It's hard to do it when you're stressed out about other things.

And a lot of times, I'll think by myself. But when it's most valuable is when I'm sitting around my students and thinking. We come up with several ideas per day, just going back and forth between us. Just like something we came up with last week, I'm like, why didn't I think of this 10 years ago? But it was the combination of other experiments starting to drop in place and going, okay, maybe. It wasn't directly linear thought, but it was because we'd seen different things drop into place recently and then brainstorm with a really great postdoc of mine-- and it was a postdoc -- oh, okay, well maybe. I said, I'm so excited about that now.

INTERVIEWER: Do you have a specific process for if you're going to go think by yourself or with your group? Is there a certain process go through or do you look to certain things for inspiration or go to a certain place?

BELCHER: Well now I almost get no time to myself with two kids, and so there's no time. Now airplanes is a good time, when I'm flying off for some place. But it's more what I do is go through my lab where my students sit, if I'm lucky, a couple times a day. And again, it's one of those completely guilty pleasures because I'm so excited to go do it. And to sit next to them at the desk and start talking about things. And some of it can really be catalyzed by grant proposals we need a write or something, and we start with that point. Or an interesting piece of data came out that we really didn't expect, what does that mean? And just talking back and forth.

So I'll walk around in my lab or in my students' work area, just sit with different students, walk around, make my way through there a couple times a day, and talk to the students about what their ideas are, what they're thinking, what their data is. Then we brainstorm from there. And we'll have meetings where students come into my office, we'll sit around a table and start thinking of ideas and talking out loud and see what comes out, and that's very, very fun. I used to get to think by myself all the time. Not so much anymore.

INTERVIEWER: Back before you had kids, were did you think by yourself?

BELCHER: Well actually, commuting in the car was a really great place to think. And it was also in my office and at home, because my brain is never really turned off. I'm always thinking as I'm falling asleep and wake up with ideas.

INTERVIEWER: That's interesting. Many of the people who have been interviewed for this are emeritus people. And you have decades of work ahead of you. Do you have any dreams of what your work might lead to? If you think 40, 50 years ahead, what could your battery and your solar cells and all, where could they be?

BELCHER: Well, I don't think it's so much about our batteries and solar cells in 40 years. What I think about is clean manufacturing. I think about a process where we can process materials under conditions that are completely compatible with their environment, and they're very high, clean, technological materials. I think about smarter materials which also can make adjustments based on their environment. I think about self-repairing materials where-- I've talked about this quite a bit-- where you drop your phone, which we did recently, cracked the face, and it can repair itself. So I think about things like that. I think about cleaner, smarter, new ways of manufacturing materials. And the reason I say I don't think about the batteries or the solar cells because I think those are going to be integrated and do well. Technology moves so fast. Those are going to be integrated and are going to be used in under 10 years. And then we'll need to move on to other kinds of a devices, other kinds of architectures than those.

INTERVIEWER: The idea of clean manufacturing and green technology comes up a lot when you talk. Is that something that's been part of your thinking from early on? Or is that just a happy artifact of--?

BELCHER: No, it's something that's been-- when I thought about the abalone a lot, I mean it just makes sense. If you just take examples of organisms in the ocean that do such a beautiful job and have done such a beautiful job over hundreds of millions of years, they've done it because they're not killing themselves at the same time. It's something that I'm obviously interested in for environmental reasons, but it makes sense. It makes sense to, if you're going to have an ecological system that is manufacturing things, that they're not killing themselves and killing their environment. And so it was really rooted in not, oh, I have this idea of really clean manufacturing-- which of course, a lot of people do, and I do of course really like the idea, but it just makes sense.

And I'm a practical person, I'm an engineer. I want to make things, I want to make things that work. I want to make things that are useful. And so, how do I do it in a sustainable way? It's not this idea that I have to make the world a better place-- which I do-- but it's just, why would you not?

INTERVIEWER: It's interesting. We're almost out of time, but I have one last question. It's just interesting, all this stuff you've talked about from your childhood of wanting to invent and wanting to make the world a better place and you're interested in medicine, it seems like you've actually been able to realize all that. I mean, I'm sure it's because you've planned it.

BELCHER: I didn't plan it. I've always followed my passion, and I think that's the key. And that's one of the things that I think about with helping students or helping my own kids. How do you help people just facilitate them following their passions, what they're interested in? Because if you do, then I think the road opens up. And I feel like that's the way it's been to me. In terms of what you said, going back to wanting to be an inventor in my garage as a child, to medicine, and following, biology, it all came true. I feel like that's my life. What would happen if everything you ever wanted would come true? And that's my life.

INTERVIEWER: Wow, what a wonderful way to end. Thank you very much, and thank you for sitting with us, it was a lot of fun.

BELCHER: Thank you.