[SLICE OF MIT THEME MUSIC]

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

PRESIDENT RAFAEL REIF: I see the work at MIT every day. I see a future. I see a future in which we can address the climate change. I see a future in which we can address and have very ubiquitous use of green energy. I see a future where we can address and solve the issue of fresh water and food. I see that. I see it here in the labs. It's happening.

HOST: That's Rafael Reif, MIT's 17th president, speaking at the Tech Day program during Tech Reunions this June. With a record 4,401 alumni and friends in attendance at Tech Reunions in 2016, Tech Day provided an opportunity to share insights and updates on the MIT Campaign For A Better World, a $5 billion comprehensive fundraising initiative which launched in May 2016.

REIF: This is a different kind of campaign. This is not a campaign for MIT. It's a campaign from MIT. It's a campaign for the world. It's a campaign to make a better world.

HOST: Today on the Slice of MIT Podcast, You're going to hear audio from a few different talks given by alumni faculty at Tech Day, which focused on two of the six themes of the comprehensive campaign. First, teaching, learning, and living, and second, the health of the planet. The other four themes are discovery science, human health, innovation and entrepreneurship, and the MIT core.

This episode will give you some valuable answers to questions like, how many pounds of trash do most Americans throw out in a day? How many elements of the periodic table can be found just in your smartphone? What can be observed in children before kindergarten that may predict their future reading ability? Or what aerospace engineering technology could be perfectly suited to a new education model? Find out this and more.

First stop, Karen Willcox to talk about education.

KAREN WILLCOX: We're seeing an unmet demand for higher education at a scale never before across the nation.

HOST: Karen got her Master's from MIT in 1996 and her PhD in 2000, both in AeroAstro. But today you'll hear her discussing her work in education innovation. She's a Professor of Aeronautics and Astronautics, co-director of MIT's Center for Computational Engineering, and the US department of Energy's Diamond Center. Professor Willcox says that one of the biggest obstacles is meeting challenges of access and affordability, but at the same time, maintaining quality.

WILLCOX: Here at MIT, we're really rethinking our education model, recognizing that we need to innovate the way in which we educate the next generation of leaders who are going to solve some of the world's most pressing problems. So it's a challenging time, but it's also exciting because of the opportunities. And in particular, digital technologies are revolutionizing the way we teach. They are revolutionizing the way that we interact with students and even the way that we conceive of the structure of institutions of higher education.

HOST: One of the projects that Willcox is working on draws on her field of aerospace engineering and is aptly named The Fly By Wire Project.

WILLCOX: Many of you may have heard of a fly by wire system in an aircraft. If you've ever looked out the wing at the aircraft, you're probably seeing all the control surfaces on the wing. They can move in different rates and different ways. And particularly, if you look out the window when the aircraft is coming in on approach, you'll see these control surfaces moving constantly, constantly adjusting.

And I don't know if you've ever wondered, how is that happening? There is no way that a human pilot could be controlling all those surfaces on a second by second instant. But instead what you're saying is this wonderful interaction between human pilot and digital technology.

HOST: That technology is the inspiration behind the Fly By Wire education system that Wilcox is developing.

WILLCOX: That's a really great example of humans and digital technologies working seamlessly together to achieve an engineering system performance, robustness, and reliability, things that we could never do with a human alone. Just as digital technologies help pilots to fly complex airplanes, how can digital technologies help teachers in the classroom to navigate complex situations with many different learners?

HOST: The system uses real time feedback between both the student and the teacher through the Fly By Wire app to modify assessments and assignments that adjust to the student's needs and skill level.

WILLCOX: We're really targeting the community college, because here's an example where students coming in with very varied backgrounds. And in particular, we're looking at classes in college algebra, accounting, computer aided design. These are classes where fundamental math skills are a real barrier to the students making it through their courses of study, but also where the students are coming in with very different levels of preparation based on their high school experience.

HOST: Having a teaching and learning model that can adjust to different educational backgrounds could drastically change the way students learn and have a real impact on their overall success.

REIF: Learning is something that as educators, we have been doing that for hundreds of years, at MIT for 150 years, and we still don't know exactly how learning happens.

HOST: While we still don't really know, as Reif pointed out, exactly how learning happens, MIT Professor John Gabrieli studies the brain to try and figure that out. And he's made huge progress. Gabrieli received his PhD in Behavioral Neuroscience from MIT in 1987.

JOHN GABRIELI: Neuroscience, the area I work in, is starting to give us some ideas about how we can make education better for everybody.

HOST: If we think about how and when we learn best, can we agree that there are certain days or times that our brain seems more ready to learn, that it's more conducive to taking in and processing information? Professor Gabrieli wanted to look at the brain and find out if this was true.

GABRIELI: Are we able to find in the human brain the moment of learning, when you're ready to learn, or the moment when you're not ready to learn? And on top of that, can we give you information when you're ready to learn that you'll remember, and can we give it a break when you're not ready to learn? I mean, that would be ideal, right?

HOST: Well, Gabrieli has done experiments that can do just that. By observing brain activity recorded by a scanner and watching the natural fluctuations of oxygenation in the subjects' brains, the researchers can see if the brain retains more information better at a time when it looks active, that is more ready, or less active.

GABRIELI: And what we find is this. If we send in the information when your brain is ready to learn, you remember it better than if we send in the information when your brain was not ready to learn. But we know now, with some scientific evidence, that there is a signal in your brain when you're ready to learn and when you're not ready to learn.

HOST: And that key information can be used to improve education outcomes in the classroom. Then Gabrieli gets a bit more specific about what the appearance of the brain can tell us about a person's probable intelligence.

GABRIELI: The surface of your brain has six layers of neurons.

HOST: This is called the neocortex.

GABRIELI: That compute much of what are the intelligence of humanity. Language, problem solving, thinking, and so on. And we can measure the thickness of that, which is a very coarse neuroscience measure, but it's a measure we can make. And then we can look at eighth graders in the Boston School system and ask two questions. How does the thickness of the neocortex that empowers the human brain to learn and to think, how does that vary in relation to standardized test scores, how well you read, how well you do math?

HOST: Here's what they found.

GABRIELI: The thicker the cortex of eighth graders going to Boston public schools, the better they do on standardized tests of reading and math. So that's one thing. And we expect that. There's a relationship between your brain and what you learn. In fact, you can't learn anything without a brain. All the learning is a brain mechanism, right?

HOST: At this point, Professor Gabrieli showed the audience a slide displaying a side view of the brain with red and yellow colors, which showed that greater cortical thickness correlated with better statewide standardized test scores.

GABRIELI: So now two things happen. When people see this picture, sometimes they think it's very discouraging.

HOST: But a key point that Gabrieli points out is that brain functioning is by no means static.

GABRIELI: The brain is very plastic. It's stunningly plastic. We know that in many animal research, but in human research as well. I could show you picture after picture of human brains changing as they learn. We had a summer study where people learned Chinese. You should see how their brain processes Chinese now after two months of learning compared to when it meant nothing to them at the beginning. The brain is phenomenally plastic. We can do amazing things. But we have to recognize the challenges that are in front of us.

HOST: So in other words, if we know this in advance, we can do something about it. And the brain's ability to adapt is remarkable. As John points out, much of our school systems are, unfortunately, not designed to recognize developmental delays before they happen and actually prevent them. But what if we could do that?

GABRIELI: The way things are set up now in schools, there's a way to fail model. Schools tend to wait until a child is so clearly so far behind his or her classmates. What if we could identify as a child arrives at the beginning of kindergarten, before there's any formal reading instruction, which child is likely to become a poor reader? And what if we gave that help before the child ever fell behind? And so it's a combination of behavioral analysis and brain imaging.

We've been looking at 2,000 kindergartens from 20 diverse schools in the Boston area and asking whether we can see differences in the brain before a child gets his or her first reading instruction in school that will help us identify who will struggle to read and therefore ought to trigger help to children before they fail. So we think that through a combination of measures, including these brain measures, we will be able to identify children with a wide variety of risks, and bring help to them before they ever fall.

HOST: Today's episode of the Slice of MIT Podcast is produced in association with the MIT Campaign For A Better World. At MIT, we pursue research, education, and innovation with a passion for serious impact. And we're just getting started. Learn more about how MIT is working to make a better world at betterworld.mit.edu. And share your stories with #MITbetterworld. Part of making a better world is focusing on our world.

REIF: Then we have the health of the planet. There is so much to do there. There is the issue of climate change. There is the issue of clean energy. Of course, related to climate change. There's an issue of clean water and food. That's a huge issue. Fresh water is a huge issue. In America we pay less attention to it. The population is growing, and we become eight or nine billion people, we're going to have a very serious problem, and those problems already exist. So it's an issue that we have to pay attention to.

HOST: Here to talk about addressing that problem is John Fernandez, Director of the Urban Metabolism Group, which you'll be hearing about today, and also the Director of the MIT

Environmental Solutions Initiative, Co-Director of the International Design Center, and a graduate of the class of 1985.

JOHN FERNANDEZ: So at the beginning of the 20th century, we were extracting materials, fossil fuel energy carriers, 7.4 gigatons. At the end of the 20th century, a little beyond, we were extracting 60 gigatons. This is an enormous change, and it's reflective of the building of a variety of things, including cities and infrastructure, because you build cities and infrastructure out of minerals, metals, and you then power them with fossil fuels. And around 1960, we went from a decidedly renewable material consumption society to a nonrenewable.

HOST: So with the rise of urban development, we see a drastic increase in the use of nonrenewable materials and energy.

FERNANDEZ: So more than half the people on earth now live in cities. And that changed. That switched over around 2008. And that's going to continue to increase to about 65 and possibly 70% in the next 30 years or so.

HOST: One of the biggest issues with that, he point out, is that 90% of the doubling urban population is happening in developing regions with limited resources.

FERNANDEZ: The fastest growing cities, the largest increase in population, is happening in those cities that are already stressed to deliver the life sustaining provisions, water, sanitation, power, that urban residents need.

HOST: As these cities continue to grow and develop, it's more important than ever to find better, more sustainable methods of infrastructure development and energy consumption, especially given the amount of energy cities are responsible for providing and consuming.

FERNANDEZ: There's a huge range of resource consumption in the cities today, across the globe. In developing regions, if you took everything that the urban resident consumes and you put it in a basket and you weighed it, including the energy carriers, fossil fuel energy carriers, you'd have somewhere around five, maybe 10 tons per capita. In transition economies, Eastern Europe, South America, other places in Southeast Asia, 10 to 30 tons per capita consumption. And in the developed world, North and Europe and the United States, we are going to 32 plus 100 tons per capita.

HOST: That's a huge range. So Fernandez launched a project to try to understand the range of resource consumption in cities around the world, tracking urban consumption of materials in cities, things like construction and industrial minerals and metals, as well as biomass, fossil fuels, and total energy use. They found some low consumption cities like Phnom Penh, but they're sustainable because they're really under serving their population. Then they did find several Japanese cities that achieved low consumption and sustainable models. So what do we do with this information?

FERNANDEZ: This work is meant to understand what is the future? What's the pathway towards sustainability? And just like you here, there is no single energy technology that will solve our climate problem. There is no single kind of city or a single kind of production and consumption system that will solve our environmental issues.

It's really going to be a cloud of different pathways. And for cities, it's going to be where those cities exist. Tropical cities, northern cities, developing, developed cities. There will be a number of different models. There's an enormous amount of work ongoing. There's an enormous amount of work to be done.

HOST: For MIT Professor Elsa Olivetti, making the world a better place starts with a better understanding of the materials we use and throw out each day. Olivetti is the Thomas Lord Assistant Professor of Material Science and Engineering and earned her PhD from MIT in 2007 in Material Science. She talks about some of the lesser known side of the environmental debate, things that she calls complicated and juicy. Elsa told the Tech Day audience that according to the US Environmental Protection Agency, in 2007 the average person in the US threw out around four pounds of trash per day.

ELSA OLIVETTI: What if we think about instead what base of materials is required for you to live your lives? To drive your cars, the mining that you do, the devices that you carry. So let's think about how much material is roughly associated with your daily life. So it's about 180 pounds per person per day. So about 40 times what we throw out day to day is required, is an inflow to support the way we live.

HOST: Next Olivetti asks the audience to think about the materials that are required just to make our smartphones.

OLIVETTI: So in the 1980s, we had 11 elements. And then in the 90s, we added four. And then in the 2000s, were up to 45. And now we essentially carry the periodic table in our pockets every day.

HOST: Recycling is touted for conserving natural resources, preserving the environment, and saving landfill space. Of course, Olivetti isn't saying that we shouldn't recycle. But she describes how it can get complicated. In this case, when it comes to alkaline batteries.

OLIVETTI: California a couple of years ago passed a landfill ban. So we weren't going to be throwing them in the trash anymore if you were in California or in New York. We needed to recycle them. So we looked at, was it environmentally beneficial, given the state of technology and the distribution of that technology in the United States, to recycle an alkaline battery? Here's an alkaline battery. Its dominant materials are manganese, steel, and zinc.

There are basically four facilities within the United States that were managing these batteries, because the battery industry has worked very hard to get mercury out of them. They were sort of essentially as close to dirt as you could get. And now we were proposing driving them pretty significant distances around the country to recycle. And what we learned through this research is given the policy as it was put in place and the financial support to manage it, it was actually environmentally better to throw the batteries in the trash than it was to recycle them. And still today that is largely true.

HOST: After making this discovery, Olivetti worked with the battery industry to begin disposing of alkaline batteries in electric arc furnaces, which are scattered throughout the country. These furnaces heat charged materials by way of an electrical breakdown of gas. Modern electric arc furnaces can be very highly efficient recyclers of steel scraps or other metals. And because there are many of them, proved more energy efficient and environmentally conscious, in this case.

OLIVETTI: I'm going to just end on this brick that we've developed that's based on waste ash. So we worked with an industrial cluster in northern India and recovered the ash that they were producing from their paper mills. And based on taking advantage of the chemistry associated with this brick, it's activated with sodium hydroxide, plus the ash, plus a little bit of clay and a little bit of lime. And we're basically working with this community to replace their red bricks, the typical bricks you think about, that are centered at 1,000 degrees C with this room temperature cured brick that's made of the ash of the region.

HOST: And Olivetti he has been working with one town in India in particular to make these bricks using their paper production waste and building them into structures and buildings.

OLIVETTI: So what I want you to think about is think about each of these bricks that you're replacing the red bricks and concrete blocks that we work with today to try and build the cities of the future.

HOST: These four alumni professors have given us a lot to think about, and they've only just scratched the surface of what's going on at MIT to help our world through improved education and solutions for a healthier planet. Head to the Slice website, slice.mit.edu, to check out some of the images from these presentations. Or watch them in full on our YouTube channel. A special thanks to John Gabrieli, Karen Willcox, John Fernandez, and Elsa Olivetti.

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