Beth Bamford:

Research is really important because by definition it's the only way to get new knowledge. There's so much that isn't yet known that it's just a cool time to be in science.

Cole Cullen:

I think at the end of the day, what really gets us out of bed in the morning is just the curiosity, trying to understand things we didn't understand the day before.

Beth Bamford:

Welcome to Reach, the podcast that tells the stories of researchers, their studies, and how their work impacts you and the world you live in. I'm Beth Bamford.

Cole Cullen:

And I'm Cole Cullen. Today we're going to tell you about research being done at Penn state that is helping developing countries.

Beth Bamford:

Our first interview is with Dr. Jonathan Lynch whose research includes growing plants in areas where hunger is prevalent because plants struggled to grow.

Cole Cullen:

It's pretty interesting because Dr. Lynch's research team also includes social scientists because not only do they want to grow these plants, but they also want to look at what growing of these plants will do socially to the area.

Dr. Jonathan L.:

My name is Jonathan Lynch. I'm a distinguished professor in the department of plant science. I came to Penn state from the International Center of Tropical Agriculture with headquarters in Columbia, South America, which is an international organization devoted to food security.

Beth Bamford:

And what made you interested in that line of work?

Dr. Jonathan L.:

I was perhaps nine years old. There was a famine in Africa and I saw it on television, and it concerned me, and I thought, "I'd like to grow up and do something about that." And so I didn't know at the age of nine that there were things like professors of plant nutrition, but I knew I want to do something about this and if I got training in plants and soils, I could help develop solutions for this. So I conceived this notion to study plants and how they adapt to the environment. And that is what I have done for my entire career here.

Beth Bamford:

You're a much more mature nine-year-old than I was.

Dr. Jonathan L.:

The goal of our research is to understand how plants adapt to stressful environments so that we can develop better plants that produce more food for poor people in developing nations and also produce plants that are easier to grow in rich countries like America. So we try to understand the mechanisms by which plants can do this and then move those traits into crop breeding programs to develop better crops, crops for the future, crops that need less water, need less fertilizer, that are more tolerant to heat, and drought, and stress. We currently have about 850 million malnourished people and that number is growing in Africa. It's expected to significantly worsen the century because of growing population, and poor nations, and the accelerating effects of global climate change, and soil degradation, and other things that are making it more difficult to grow food for these people. And so part of the challenge of this generation in this century is to figure out a way to sustain 10 billion people in a degraded natural environment.

And there's multiple components of that, but one is certainly just being able to grow food. Now because in poor nations, they don't have access to water and fertilizer, their yields are quite low, often five or 10% of what they could be because the soils are bad, the weather is bad, and the plants are under stress. Now, the flip side of that is in rich countries like America, we also have drought problems and there's limited amount of fresh water resources, but we fertilize our soils. But intensive fertilization creates a lot of environmental problems and it's very expensive for the farmers. So even here in America, we'd like to use less fertilizers. So this issue of low soil fertility as a primary cause of food insecurity in poor nations and it's a primary cause of environmental degradation in rich nations. So understanding how plants adapt to soil conditions and improve that through plant breeding, through breeding better plants has significant benefits for humanity.

You have to imagine, for an American beans are just an occasional thing you have in Mexican food or something. But for these people in communities in Latin America or Africa that really rely on beans, this is a staple. It's very important in their diet. And these people cannot afford animal protein in many cases and I think this is one of the reasons they're so highly priced in these systems. If you are hungry and don't have a lot of food and you have to work all day, you want something that gives you energy and stops the hunger. Beans will do that. I tried that. Have beans for breakfast and you probably won't be hungry for lunch. They really stick with you. And they have the protein, iron, and zinc. They have these other nutrients that are antioxidants. These are very healthy things in beans that you don't find in these staple grains, so they are perfect compliment.

Our strategy was let's compare bean plants that grouped fairly well in a low fertility environment or under drought versus those that did worse and try to understand what was that difference, why were these plants different? And we tried lots of different ideas, and approaches, and began to realize it was all about the roots. So it took us years to figure out it was roots and different things about roots and these were just discoveries that people hadn't made before in any crop. It wasn't as if we were just doing and being what other people have figured out. It's like people didn't know these things about roots. So that was phase one, was what are these root traits?

Phase two then was happened with select for them. So we thought of things we could look at in young seedlings in the lab or in a simple system that would allow people to select for better root traits. And then an additional step, once we identified these traits and could screen many, many lines because breeders look at thousands of lines to find the best ones, right? So it had to be so called high throughput. We had to be able to do it in a quick and cheap way, especially in developing countries.

So once we had those techniques, then we began to use those methods to try to understand the genetic control of these traits. And then generally these are complicated traits. Plants have been working on this for half a billion years. So if there's a single gene that suddenly makes you do better, generally plants have already thought about that and have already found that gene, right? So the differences we're going to see now is like, well different gradations, or different amount of this trait or that, then there's some kind of trade off involved. Otherwise, if something was always a good thing for plants to do, they would all do it.

And now knowing the traits of interest, the potentially useful traits, and something about their genetic control as we move towards deployment in breeding programs, we have an ethical obligation to understand something about how it's going to actually affect the cropping system and the communities before these are moved out into application. So, for example, in America you might think if we have a better bean plant that's superior to existing bean plants, some seed company will sell it and people will grow it and everyone's happy. But in Africa, there are many regions of Africa where it's quite different. There are no seed companies. Seeds are not bought and sold. They're traded among friends or neighbors. And then you plant the seed and then save some seed from your harvest to plant the next year. And we wanted to make sure that introducing these lines with better roots, this was not going to have negative consequences for these people.

In the case of Southeastern Africa, we've done a lot of work in Mozambique, and Malawi, and Zambia for ... We have projects there. They're very poor countries. Have food insecurity and they are very reliant on beans as a source of nutrients for the family. It turns out that different kinds of beans, and this is work done in collaboration with other people, with other disciplines like social science and breeding and so on. And it turns out that, some types of beans are sold in the marketplace. And these poor countries, agriculture is often the primary economic activity. So you're not only eating from your land, you're surviving. This is your livelihood in terms of money as well as food.

So the many households, it's the men who handle marketing, but it's the woman who might be growing the beans generally. So if the woman grows this type of bean and we can improve the yield of that bean, what will happen? The man will have more beans to sell in the marketplace. And then in looking at what's in many interviews with people, what's likely to happen if the man makes more money from selling beans in the marketplace? Well, it turns out the first thing the person is likely to do is buy more beer.

Beth Bamford:

Oh, I thought you were going to say land.

Dr. Jonathan L.:

No. Well the people don't own their own land. And that's the point. The men will say that they have to buy beer to drink beer with the village leadership because they do not own their own land. And so by ingratiating themselves with the village leader, then they're more likely to have the family have a good allocation of land in the future. Having extra income, significantly more income, the man might marry another woman. So there are areas of Mozambique that are polygamist and the more successful a farmer is, the more wives he will have, see. So that's a certain kind of outcome.

You might think, Well by improving the yield of beans, we've helped feed the children." Which is our thought going in, but actually men bought more beer and married more women or something like that. But now if we improve the yield of another type of bean that has no market value, it's not sold in the marketplace, it's perfectly edible, perfectly fine bean, but it has no market value, well the women will use that to feed their children. You see, so very different outcomes just based on the color of the seed. It's the same plant. It's just a different seed color. Now that's just in a nutshell is kind of an example of the kind of social consequences that we have to think about as outside researchers. You have to be sensitive to the social system and the economic system that's in place. If we're trying to improve things, we want to make sure we're having a positive impact. Right?

We just went through the official governmental release in the country of Mozambique to release three new bean lines and with more in the pipeline that now are going to be available to farmers in Mozambique that have much better yield, twice as much yield as before, in these stressful conditions, which should have a significant benefit for nutrition of the family and income of the family and these other things that we studied because beans fix nitrogen from the-

And these are the things that we studied. Because beans fixed nitrogen from the air, these new plants will actually fix more nitrogen from the air and contribute more to soil fertility. Because they're bigger plants, they protect the soil from rainfall and so there'll be less soil erosion. So we're hoping that there's going to be a significant benefit from these new plants in these regions. So we're hoping to move them beyond that kind of poverty trap. So if you can get more yields without inputs, now with that extra money, extra food, perhaps you can afford to buy some fertilizer or buy [inaudible 00:00:33], begin to develop and maybe get a bigger plot of land and maybe people begin to get educated and move to jobs in a city or something like that. In the long run, we don't want people practicing this kind of low-yield, low-input agriculture.

When people are hungry, they're desperate and they'll rise up against their government. They'll fight with their neighbors. They'll topple their leadership because they can't eat. Their family's starving. This kind of social unrest in addition to the direct harm it causes those people in those communities ends up involving America.

For example, the Arab spring in North Africa that caused a lot of unrest and toppled governments still has repercussions today, was caused by food shortages because of drought. Hungry people rose up, toppled their governments, a lot of unrest was created that causes global implications. So we're all connected, we're all people, we're all on the same planet and it helps all of us if we can make sure that people have enough to eat.

PART 1 OF 3 ENDS [00:11:04]

Beth Bamford:

So, solve world hunger and you'll have world peace.

Dr. Jonathan L.:

I think that's a major step towards world peace. Certainly the opposite is true. If people are hungry, you're not going to really have world peace.

Beth Bamford:

So can you tell us something that you felt you were really successful at throughout your studies?

Dr. Jonathan L.:

Yeah, well I think we've uncovered a lot of interesting research results that helps us understand how to make better plants and also helps us understand plants and how they adapted to life on earth. But I think my most significant feeling of accomplishment or achievement is working with young people and helping train them and helping develop their careers.

And you know, it's humbling if you think about, I really feel like this generation, the young people today are going to confront a challenge of unprecedented proportions in human history. We've never had this many people on earth and we've never had a situation where the environment is being degraded so rapidly. And so how are we going to match that up? How are we going to have 10 billion people who already, we have massive problems of poverty and malnutrition and insecurity. It's only going to get worse. So it's like a civilizational challenge. It's an unprecedented challenge and it's this generation, the young people who are going to have to come up with solutions to this problem and it's going to have to happen in many areas. One of them certainly is figuring out how to produce enough food for everybody. So I feel like my most significant achievement in my career has been to help these young people and prepare them for this challenge so they can do what has to be done.

Cole Cullen:

Our next story is about toilets.

Beth Bamford:

Toilets? This is a podcast about research.

Cole Cullen:

This is indeed a podcast about research, but this story is about toilets. Our next researcher is Tak-Sing Wang, you may remember him from our materials episode. He is the director of the Laboratory for Nature Inspired Engineering and they are developing technology to improve toilets that will actually help in developing countries.

Tak-Sing Wang:

The Nepenthes pitcher plant, which [inaudible 00:15:07] that captures insects for its food source. We are very interested to look at why this plant can capture insects and one of the reasons is because they have this very slippery surface that has evolved on top of this plant, so our group tried to understand the mechanism and replicate this slippery coating and use this coating for [inaudible 00:15:29] scenario.

For example, our lab has developed this slippery coating that you can put it onto toilet so that nothing can stick to it. It has a very important implication in water conservation because if you don't have things sticking on the toilet then you don't need that much water to clean the toilet, as well as you do not need that much chemical cleaning agents to clean the toilet. And just recently we got our very first funding from the National Science Foundation who helped further supporting the commercialization and research and development activity to roll out this product. Hopefully one day people could use it.

Cole Cullen:

So it's beyond theory at this point.

Tak-Sing Wang:

It's beyond theory. We actually make the real object. We've had a few real experimental demonstrations. And since then we actually got a lot of interest from the public.

Very recently our group has discovered this new material, a self-healing material that is replicating the self-healing property of biological cell membranes. So in the microscopic world, biological cells, they can engulf other objects of similar size without leaking out it's own internal cellular content. So in a way that the cell membrane can let large particle to go through, but blocking small objects from releasing out from the cell body.

One of the reasons why they can do that is because this cell membrane is self-healing, meaning that when that large object punctures through this membrane, it can self-repair itself. And I'm inspired by this phenomenon. One of my former PhD students, Birgitt Boschitsch, has developed this membrane, we call it like a self-healing liquid membrane. What it allows you to do is to let large particles go through but blocking small particle. And this is very different from the regular filter, all the way from [inaudible 00:17:26] coffee filter to water desalination. Right, those filters, let small particles through but blocking large ones. But this membrane we've developed is like a reverse filter.

Cole Cullen:

Slippery surfaces is a technology that's going to help the toilets as well as your reverse filtration is going to help the toilets.

Tak-Sing Wang:

Mm-hmm (affirmative).

Cole Cullen:

Can you explain how, because they're kind of two different... okay.

Tak-Sing Wang:

Right, they are two different things. So slippery surface is going to help to prevent things from sticking into it. For example, like liquid and solid waste, those obvious, and including bacteria. Like we have some that are slippery surfaces has a very good antibacterial property. So that's one aspect.

And for the reverse filter, the liquid membrane, it's going to prevent unpleasant odor from escaping from the toilet while allowing liquid and solid waste to pass through. So that is another aspect of that.

Water scarcity is a global problem. Literally half of the world's population doesn't have enough water. So being able to save water from aspects such as water flushing, the toilet flushing, I think would make a really big impact. In the developing world if we can save flushing water as well as the chemical usage, I think, that not only will be important for water conservation, but also protecting the environment. By putting a slippery coating in the toilet, I think that would make waterless toilets more appealing because waterless toilets, their waste sticking on the surfaces. That is where the bacteria grow. That is where the unpleasant odor comes from. If we can prevent that from happening, I think that will make a big impact in sanitation and also promoting health as well.

Cole Cullen:

Our final story is about using 3D printing in architecture.

Beth Bamford:

My son came home from school the other day with a 3D printed box, which I believe is using basically the same technology just on a much smaller scale.

Cole Cullen:

It is the same technology and your son's box was probably made out of plastic, but these researchers are using more traditional building materials. Just through a 3D printer. We spoke to two researchers from the College of Arts and Architecture who are using 3D printing to build affordable homes that they hope will impact the global housing crisis.

José Duarte:

My name is José Duarte, and I am the director of the Stuckeman Center for Design Computing at Penn State.

Shadi Nazaryan:

My name is Shadi Nazarian, I'm an assistant professor in the Department of Architecture at Penn State.

Cole Cullen:

How did you two start working together?

José Duarte:

Well, I saw a presentation by Shadi and I found some similarities with the work that I was doing and I found her work very, very interesting.

Shadi Nazaryan:

So when José first came here, I invited him to my lab and explained what I was doing and I showed him a project where I was uniting different materials seamlessly. And José was also interested in doing that. So I was trying to create a graded transition between concrete and glass to gain a different variety of structural optical thermal properties. And José was trying to do the same thing.

José Duarte:

Yeah, I was working on the transition between cork and concrete. So at the end of the day we, you know, this is basically the same idea, with just different materials, maybe we can combine the three of them.

Shadi Nazaryan:

And we call it functionally graded materials.

José Duarte:

Functionally graded materials are materials that are composites that you can obtain by mixing different materials together in different gradients to achieve different properties.

Shadi Nazaryan:

Functionally graded structures are structures where the properties and performance of the structure can vary and morph along the length of, for example, a wall. It could be more structural at one side and have more thermal properties or visual opacity or transparency in some areas where needed.

Cole Cullen:

What would a wall look like if you were combining two materials, one of them being glass and the other...

Shadi Nazaryan:

Right. So to do that, you need to use composite materials.

To do that, you need to use composite materials. Concrete is a composite material. There is different ratios of different materials, different elements in there. So glass has been used as a aggregate in the past in the formulation of concrete. But the way I was interested in using it is not just to use it as an aggregate but rather use it as transitioning from on one side, being completely a concrete wall and gradually change it's performance, it's properties, until I get to total transparency. But to do that I needed to find material scientists to make this possible, and when I came to teach here at Penn State, I approached material scientists, and we partnered and made this possible.

As a result, at the end, the wall that you end up is a ceramic, it's an advanced ceramic, not ceramic as in pottery, but advanced ceramics have really different types of properties than regular ceramics. They could be optimized to perform well structurally much better than a regular concrete wall would for example, it has advantages.

PART 2 OF 3 ENDS [00:22:04]

José Duarte:

What happens is if you have a wall, when you have loads on the wall, the structural requirements are not the same in all the points on the wall, they vary. The idea was to customize the design of the wall so that when you need the wall to be stronger, you would have more sand for instance, when you need the wall to be, to have battery thermal insulation of properties, you would have more cork. That's why we got the idea of a change in the gradient of cork and sand to optimize the design of the wall. At the end of the day they say, 'Now, what we are doing are customizing the materials. We are not just customizing the layout of the house, we are also customizing the design of the building parts and the design of the material itself."

If we can design and make components, building components with high performance, we can, for instance, save energy. We need less energy to operate the house, to make the house warm in the winter or cooler in the summer because the design of the wall is optimized for that purpose, so that's one big advantage. It's also cheaper to build. Therefore, the house can potentially be cheaper and it's takes less time to build as well because they're not as many people involved and everything can be automated. So there are advantages. Cost is one, high performance is another one, and even in terms of aesthetics, because if you use additive manufacturing we can actually play with different colors or with different textures, so you can have that as well. There's many advantages, I think.

Cole Cullen:

So how do we build these magic walls? Kind of give me the process, and if you can compare it to, you say 3-D printing, people think it's a box like this that makes fun little plastic figurines, so kind of compared, what people might understand 3-D printing to be, compared to your process.

José Duarte:

It's a very similar to what you are saying, except it's at the larger scale. You basically, you have a digital model of the parts that you want to make, and that digital model has several layers of information, so it has the dimensions, the geometry, but it also has a material composition of the building component. Then what you have, you use that digital file with information about the geometry and the material to make the wall using a machine that basically uses different materials and joins them together and then deposits them with the right gradient at the right location in space. That's basically the idea, so it's very similar to the usual plastic 3-D printers except that we're not dealing with plastic. We are dealing with concrete, and cork, and glass, and even metal.

Shadi Nazaryan:

One of the things that 3-D printing makes possible for example, is to the continuity of production, nonstop production. Other things that it makes possible is the ability to transition and morph the structure. In other words they use a functional graded materials, and creating new types of details in architecture, and new types of spatial experiences, and new types of surfaces. Transitioning without a seam from one material to another, not only it means we can achieve these new things in architecture, but it also opens up a lot of new things because we need to begin working with other disciplines much more closely. So the collaboration between material scientists, civil engineers, architects becomes a lot more dynamic and useful.

José Duarte:

If you look at these sort of architecture we see that in every age the appearance of buildings were very much dependent on the technology. I know probably the most striking example is Gothic cathedrals. They are what they are because of the technology that was used to build them, and I think the same thing will happen with these technologies. I am very excited, and very interested, and very curious about how the buildings will look like in the future when we are able to take full advantage of the technology and the descendant technology completely.

Cole Cullen:

Do you feel this technology and what you're developing is at the forefront of the next age of architecture?

Shadi Nazaryan:

Absolutely.

José Duarte:

Yeah.

Cole Cullen:

It's cool and it's science fiction-y but what's it going to do for people that need affordable housing?

José Duarte:

Usually in my talks I show a graph of the growth of the human population and it's a very interesting graph because if you look at the graph, it tells you immediately that given the increase of population over the next 20 years, you will need to build as many houses as you have built in the past 2000 years.

It's the scale of the problem. You cannot produce enough architects to solve the problem. Okay? So you need to use this technology so that you can actually build more in a shorter time. It's more affordable because the process is simplified. Meaning, it will consume less energy. It will cost less to be built and so on. So there are many advantages,

Shadi Nazaryan:

Fewer resources too.

José Duarte:

Yeah.

Shadi Nazaryan:

We will not be killing as many trees as we have been in the past.

José Duarte:

Developing countries that are those where the housing problem is biggest and therefore where we'll need to build more houses over the next 20 years. Therefore, if we can use the technology there, I think we can solve the problem.

Obviously then you know, someone can ask, "Oh, but these countries tend not to be the most developed industrially or technologically, so how will you do that?" And you need to be careful. I mean, to transfer the technology from an industrialized country to a country that is not as industrialized, but there are also ways and we are actually working on that as well. Trying to combine traditional construction techniques with this new technology. For instance, mud construction has been very much used in these countries and therefore we are also working on using earth as the material.

Shadi Nazaryan:

Soil.

José Duarte:

Yes. Soil to print. That's one way. So basically we need to understand the local context. We need to learn, we need to know what are the materials available there? What are the traditional construction techniques and see how we can selectively introduce the technology to use what they already have?

Cole Cullen:

Our podcast is about research and you guys are into architecture. A lot of people don't think of those two working together. So can you tell me why research is important in architecture?

Shadi Nazaryan:

Typically research in architecture is done through the act of design and the use of materials, developing details, different types of things. Ours is a little unusual, I must say, because we're really developing everything we need in order to produce that architecture.

José Duarte:

Also, because architecture is itself a multidisciplinary field. We deal with physics, we deal with aesthetics, we deal with...

Shadi Nazaryan:

Material science.

José Duarte:

Yeah, and so on. So at the end of the day you can connect research in any of these fields to architecture. For instance, I mean, Penn State is very good at the materials research, and they have been developing amazing materials. I think, we can add to that research by developing innovative applications of those new materials. I think, designers, not just architects, but designers and artists in general, can actually have a very important role in making sure that the research is being developed. Investment that the society is making is actually benefits society.

Cole Cullen:

When we interviewed José and Shadi, their team was in the middle of a NASA competition to use this technology to develop homes for Mars.

Beth Bamford:

We hope to cover the NASA competition and results in a future episode. Thank you for listening to Reach and a special thanks to Doctors Jonathan Lynch, Tak-Sing Wong, José Duarte and Shadi Nazarian.

Cole Cullen:

And don't forget, all the episodes of reach can be found on our website. Please consider making a contribution to WPSU so that we can bring you content like this. Visit wpsu.org/donate. Thanks.

PART 3 OF 3 ENDS [00:32:53]