Future Farmers of Our Solar System: Growing Gardens in Microgravity – Season 2, Special Episode

Amy: Hey everyone, this is Amy Bell from Louisiana Tech University, and you're listening to a very special episode of Beyond 1894.

Amy: On December 2nd, 2020, the SpaceX Falcon 9 rocket is scheduled to launch from NASA's Kennedy Space Center in Florida. It will be delivering science investigations, supplies, and equipment to the International Space Station. One of the deliveries will be a new technology developed here at Louisiana Tech University by Dr. Gergana Nestorova, an Assistant Professor of Biology in the School of Biological Sciences.

Amy: While NASA is taking steps to expand space exploration, they need to ensure astronauts on longer missions—like to Mars or to the moon—will have all the resources they need to successfully complete their mission. One of those resources is food--fresh, nutritious, food—that will help sustain the astronauts in an environment that will not.

Amy: Right now, astronauts are dependent on regular shipments of freeze-dried and prepackaged meals, but the farther they travel from Earth, the longer it will take for them to receive those shipments. These meals, like other food, will break down and overtime become less nutritious. If astronauts have to survive without a new shipment for months or years, their prepackaged meals may spoil before the next shipment's arrival.

Amy: Listen to astronaut Serena Auñón-Chancellor as she talks about the food she and her team eat in space.

Dr. Serena Auñón-Chancellor: What type of food did we eat? So, you know how the military eats MRE's? Have you ever seen these green packets with mushy food inside? Yeah, that's what we ate. So, most of our food was in those packets. What do you think is one of the most popular fresh foods we have up there? Tortillas. Tortillas lasts a really long time, and you can put anything in the tortilla. So, I got really good at peanut butter and jelly tortillas. That's one of my favorites. That's the closest I could get to a peanut butter and jelly sandwich.

Amy: So, right now, on the International Space Station, astronauts are experimenting with growing different types of produce in a small, vegetable, space garden.

Dr. Serena Auñón-Chancellor: We were having a lettuce happy hour here, we just harvested a bunch of Dragoon lettuce, they are on ISS and really enjoyed it cause we don't get a lot of fresh fruit and vegetables.

Amy: I mean, agriculture was foundational in establishing human civilizations on Earth, and similarly, it will be the key to colonizing another planet. However, everything in space is made up of different elements and different atmospheres, so our methods of farming would have to be reevaluated and tailored to these new environments.

Amy: Here is Dr. Nestorova explaining the research.

Dr. Nestorova: One of the main functions of the International Space Station, it serves as a lab for space experiments. So, scientists from academia, industry, government, they have experiments, and they're looking at the effect of space, more specifically gravitation, microgravity, on cells, animals and plants. So, this is a big area with the plants. Very interesting area of research because now as we plan to expand and colonize different systems, starting with the Moon and Mars, hopefully in the near future, yeah. We need to know how to grow plants, which genes are important for the plants to grow in microgravity, how they change, so that we can develop the best crops on Earth to grow on Mars.

Amy: Dr. Nestorova has developed an instrument that could greatly improve the way plants are being observed and analyzed on the ISS.

Dr. Nestorova: Currently, many of these experiments are done on ISIS. It is on space. On ISIS, space is very limited. You don't have much space, and the astronauts, they don’t have a lot of time.

Dr. Nestorova: So, currently, the system that is on ISIS, it's a module, which is destructive to the samples, and it's not very appropriate for plant material. So, very often the plant experiments that perform on space, and then the samples are frozen, and brought down on Earth for genetic analysis.

Dr. Nestorova: Now, with this technology, we are extracting non-invasively, we don't disturb the sample. It takes two minutes to extract the genetic material to capture the genetic material on the surface of this probe. And then we directly use this probe in an instrument for amplification of the genes. We also don't use any liquids. It's a solid phase extraction without any liquids. And without lysis buffer. So, that also simplifies this process.

Francesca: My name is Francesca Weiss. I am a biology major, chemistry minor, and I'm on track to graduate in March of 2021.

Amy: Francesca is Dr. Nestorova’s undergraduate researcher, and she helped introduce me to the research they’re doing.

Amy: How did you get involved in this project?

Francesca: Well, that's kind of a funny story. I'll just preface it with the fact that I consider myself a nerd for all things space, since I was very little. So, it all started when Dr. Serena M. Auñón-Chancellor came to speak at Tech.

Dr. Jamie Newman: Please join me in thanking and welcoming Dr. Serena M. Auñón-Chancellor to Louisiana Tech University.

Francesca: And she is a medical doctor and astronaut. So, she came to talk about the medical research that was happening on board the ISS.

Dr. Serena Auñón-Chancellor: We do everything from DNA to RNA sequencing, to cancer therapy research that as you can see on the lower right there. Hundreds and hundreds of experiments, some of which I'll talk to you about today. I had the great privilege of being able to grow a lot of plants, I work with two different plant habitats while I was up on station, and there is nothing that smells better than greenery growing up there. In very sterile environments, the only place, the only thing, that smelled like Earth.

Francesca: And my dad and I both went to that talk. And then the next day, I went to a tri beta meeting, which is the Louisiana Tech biology club, and the topic was undergraduate involvement in research. So, one of the projects presented was Dr. Nestorova's ISS project. And as soon as the presenter said, NASA, I was like, hooked. So, I immediately emailed her reached out, and she took me on the next month.

Amy: Wow. So, how long have you been on this project?

Francesca: Since December of 2019.

Amy: Can you explain the project in your words?

Francesca: Sure, I consider myself a relatively new member of a team because I was trained for probably six of those 11 months. So, essentially, we're trying to develop a one-step gene sampling device, so that the astronauts onboard the ISS can analyze genetic material in a safer and more efficient fashion.

Francesca: Right now, the astronauts are required to lyse a biological sample, which essentially just means to cut it and introduce it into a microfluidic system. And then they can test the RNA. So, our project is based on a functionalized needle, and all they have to do is poke it into plant matter for two minutes, pop it in the PCR, and test it. Wow. So, it'll make it pretty significantly more efficient.

Amy: When I spoke with Dr. Nestorova about her technology, she patiently broke down the science for me, and together we created an analogy to help me understand how her technology works.

Amy: I'm going to try to visualize it. Um, you have like, you have this life form, right, that's full of DNA and genetic material, and you're putting this little needle in it.

Dr. Nestorova: Mm hmm.

Amy: And you have something on the surface of this needle that all this genetic material is going to attach to? Correct?

Dr. Nestorova: Yes.

Dr. Nestorova: Yes. And then you can take out the needle and have all of the genetic material that you're interested on the surface. Mm hmm.

Amy: So, basically, that genetic material, it's ideally, it's the same, like it's the same as everything else within that life form, right? Because you're getting a little tiny piece, but it's kind of like, ugh, I guess it's like getting… like chopping off a little tiny piece of bread, of a loaf of bread, like that little loaf of bread tastes the same as the rest of the loaf of the bread.

Dr. Nestorova: Yes. So, you're sampling just a small piece that represent exactly the…

Amy: The whole thing.

Dr. Nestorova: Yes. The whole sample. The whole biological….

Amy: Yeah, and so, you have this needle, it has the genetic material attached, and then you place it in a tube?

Dr. Nestorova: Yes, we place it in a tube. And this tube already has all of the materials for the amplification… to replicate it.

Amy: So, to basically make a whole other loaf of bread?

Dr. Nestorova: Mm hm. Multiple loaves of breads, like, like a million breads. Out of this tiny, tiny….

Amy: Yeah. Wow. Okay.

Dr. Nestorova: So that we can actually see what is actually going on in this cell on a genetic level. So, it's kind of a magnification of this little….

Amy: Crumb of information.

Dr. Nestorova: Yes, this little crumb of information is further magnified to show what's actually happening in the cell.

Amy: Yeah. And so, you said that this process is noninvasive. So, what does that mean? So, like, by taking this little crumb from this loaf of bread, does that mean that you're not going to see a hole in the bread?

Dr. Nestorova: Yes, exactly. You're not destructing the sample. If you need, you can go back and take another crumb from the sample, you know, insert this RNA capture probe inside the sample and get more genetic material. And if your sample is plant, it will continue to grow. You have plant species growing and you can sample. Also, you can sample a very tiny area. And you can compare the crumbs from one part of the sample to the other. For example, in a plant, you can compare a crumb from the leaf to a crumb from the root. You can also have the same plant that is growing, you can take a little bit of a crumb from the sample, or insert your probe inside the sample, and check what's going on with the sample as it grows. For example, how is this gene x changing every week as the sample is growing?

Amy: So, the genetic material will change week by week?

Dr. Nestorova: Yeah, the expression of these genes will change. So, it's not static. That's how plants and different organisms will respond to external environment.

Amy: Yeah. What do you mean by the expression of the gene? So, does that mean that, like, if you were to look at the DNA sequences, that they'll be the same each time, but they express themselves differently?

Dr. Nestorova: So, the DNA is always the same. And this DNA will be transcribed to produce mRNA which makes proteins. Proteins? These are molecules that are the building blocks of everything. You know, your cells are built of proteins, you're built of proteins, these are micro molecules.

Amy: The ingredients stay the same, but they express themselves a little differently every single day.

Dr. Nestorova: Yes, depending on, you know, what is the environmental conditions and the developmental stage of the organism. So, that's very important for space research, because you want to know which genes are expressed, which genes are important in microgravity so that you can change them if you are going to farm on Mars.

Francesca: I'll just give you a human example really quick. So Scott Kelly is an astronaut. He has an identical twin brother, Mark Kelly. And Scott spent a year on the International Space Station. And they are doing a long term study on how that affected the twins physically.

Amy: Being in space?

Francesca: Yes. So one twin stayed on Earth, one twin went to space. Wow. And Scott Kelly, the twin in space, his gene expression changed 7%. And that has to do with adapting to the environment that you're in. So same thing for plants and essentially anything living your gene expression can change to adapt.

Amy: Does that mean just that the proteins that your body is developing changes?

Francesca: Yeah, I'll try to put that into a metaphor form. Let's say that you have Christmas lights, a string of Christmas lights, and each light is a base. So, you have four bases in your DNA - you have adenine, thymine, cytosine, and guanine. Let's say each of those Christmas lights is one of those letters. We'll say A, C, T, G.

Amy: So like they are different colors of the lights. We have multi-colored lights.

Francesca: Yeah, yeah. And when Mark Kelly is on Earth, his Christmas lights light up in a certain way. So, like every other light is lit up. Now when he goes to space, and his body is adapting to microgravity, his genes change, so every two lights are lit up. So, you have the same sequence, but different parts are working. So yeah, it is essentially about protein development and how that changes.

Amy: And so, are they trying to create the best environment to grow their produce, basically?

Dr. Nestorova: So, the first step will be to assess what's happened inside these plants and how they respond to microgravity and radiation, how the bacteria that grows on these plants changes in different conditions in space. And from there, I would assume that they will develop conditions to grow these plants. So, this technology actually help assess how plants respond to space environment, what changes inside the plant on the genetic level.

Amy: Yeah, that makes sense. And how is this process different from the way that they assessed plants before? I'm assuming that the way they did it before was more invasive. So, what does that mean? What did that look like?

Dr. Nestorova: So, um….

Amy: Instead of taking out like a tiny crumb that doesn't really make a difference, did they take out like bigger chunks?

Dr. Nestorova: So currently on ISS, as far as I know, most of the plant experiments, there is not enough space and enough time to process a lot of plant materials on space. When I say space, it's on the International Space Station. The module that is used for processing of the genetic material requires complete lysis of the tissue. So, most of the plants are frozen, and then sent back to the earth. And therefore, on the earth, they are lysed and analyzed.

Amy: Okay, and how did they analyze them on Earth?

Dr. Nestorova: Well, there what that really depends on the….

Amy: On their process?

Dr. Nestorova: Yes, on the application, but then, you know, if they're looking for RNA, they will start with the breaking down of the plant tissue and breaking down the cell wall of the plant. You know, plants are made of cells that have cell walls, and you have to use a buffer to break the cell wall and actually release the genetic material in the solution.

Amy: Hmm. So, does that ruin their sample? Does that ruin the plant that they're looking at? Is it like dissecting it?

Dr. Nestorova: Yes, you have to lyse it. You have to break down the sample. So yes, it will. It will break down the sample? Definitely. Yes.

Amy: If we're going with the loaf of bread analogy, is it kind of like they completely tear apart the loaf of bread?

Dr. Nestorova: Yes, the sample will be. So, the current methods for RNA purification from plant tissues, all of the kits that are available on the market, they require complete lysis from the sample. So, you have to lyse your sample, you have to break your cell wall to release the nucleic acid. And, for my application, that's not a problem. You can you can do that.

Dr. Nestorova: So currently, on space, this is how it is done. It's a microfluidic module where you lyse your sample and purify your genetic material. But on space, it takes more time. It takes valuable time, and it takes space. So, ISS is not able to process all of this plant samples so they send it back to Earth for….

Amy: But either way, it takes a lot longer of a period of time, so they can't get the results of their experiment as quickly as they could if they use your technology.

Dr. Nestorova: Yeah, so, with this technology that can potentially experiments for gene expression analysis, analysis of genes on space can be done quickly, relatively quickly on station versus, you know, sending those samples on Earth.

Dr. Nestorova: So, it will make a difference, especially in terms of plant biology, because it will allow for specimens, more specimens, to be processed and analyzed on ISS versus freezing them and sending them back to the earth. At least for gene expression analysis.

Amy: Yeah. And why is it so important that they're able to analyze it there versus having to freeze it?

Dr. Nestorova: So always when you freeze sample and then store it, and they send it back to the earth six months later, there is a slight difference in the expression of some genes, due to this freezing and storage process, so it's always better if you have the opportunity to analyze the data immediately after the experiment to prevent these artifacts and changes in the expression level of some genes due to the long term storage.

Amy: While Dr. Nestorova's technology is relatively easy to use in her lab, with the stability of gravity and a predictable environment, she is interested in discovering how practical the use of her technology will be in space.

Dr. Nestorova: So basically, with this project, we're assessing the compatibility of this technology in space. Is it easy to integrate with the other instruments and overall, how it works in microgravity environment. So, we had to do a lot of work to integrate these probes with the special holder so that they can be held in microenvironment, making sure they don't float in space, that they're in a special box. So that's, that's actually the purpose of this project: to assess how this will fit with instrumentation on ISS and whether it will be feasible that this is used.

Amy: How will everyone know if it works well.

Dr. Nestorova: So, we'll be able, we have actually, we need to be connected and support this experiment via NASA software, intercom communication, and we'll be able to actually, we should be able, we need to be connected to all of us. When I say all of us, it's me, the payload developer, that's collaboration with the NASA Ames Center, the wet lab team over in California. And we'll be able to see the same day the results from these experiments. We will be virtually, so to speak, present during the experiment and download the data from the results. So, the PCR results will be downloaded.

Dr. Nestorova: So after, if this technology works well in space, then we have to do some ground control experiments. And from there, you know, it's, it's really up to NASA to decide whether they want to, you know, utilize this as part of their set of instruments for biological analysis on space

Amy: Are you excited about, your, this technology being used on ISS?

Dr. Nestorova: Yes, I'm very, very excited. I'm looking forward to this project. And it's been, it's been the combination of, I would say, two years' work, almost two years work. This project started in 2019. It is a three years project. So, we're actually scheduled to fly, to launch the hardware, on December 2, as of now.

Dr. Serena Auñón-Chancellor: We get a couple days to rest, and then the work really starts. And so, what you're seeing here are all the cargo vehicles that come up to station with critical science cargo. You've got SpaceX HTV, in the lower left, also, Northrop Grumman Cygnus. We capture these with the robot arm, and then we have to unpack them and start all of the science.

So, we took a time lapse video of that. And you see how many people and people hours it takes to unload these vehicles. But we've got science that's waiting.

Dr. Nestorova: And the experiment most likely will be sometime in mid-December. Okay, very soon. So, depends on the harvest of the radishes and the plants. So that's when I expect to be. So, I'm very excited to see

Amy: Francesca, Dr. Nestorova's undergraduate researcher, is also very excited.

Amy: So, how cool has it been for you to be on this project?

Francesca: Oh, very cool. I can't even explain. If you had told me a year ago, that I would be this close to working with astronauts on the space station, I would call you crazy. Because I did not expect that to happen at all.

Amy: How do you think this being on this project is going to impact your career?

Francesca: So, my hope is to attend medical school in the fall, next fall. It will impact my career, maybe not so much as a physician, but in regards to research, it's really opened my eyes to that field, which I could also pursue as an MD So, inspiration, I suppose is how it would mostly impact my career. Yeah. And also, just with my, my love for space and NASA, I always thought well, maybe as an MD I'll go try and do research for NASA at some point. I've heard of MDs doing that, like Dr. Serena Auñón-Chancellor, so maybe in that way.

Amy: Well, thank you so much for doing this interview.

Francesca: Oh, no problem, it was a blast.

Dr. Serena Auñón-Chancellor: Do we need more workers, and students, and chemists, and scientists, and engineers to help us? Yes, we do, so please come join us. Cause we need you. The clock is ticking, so as fast as you can come join us at NASA, I don't care which NASA center, please come. We'd love to have you.

Amy: Do you hope that, one day, people will be able to live on Mars?

Dr. Nestorova: I hope so. I know that my husband and my son, they're following the news about the, you know, SpaceX and NASA and my son wants to be one of the astronauts on Mars.

Amy: Really? How old is your son?

Dr. Nestorova: He's 10.

Amy: Well, thank you so much for talking to me, and for teaching me a little bit more about your technology. Thank you, Amy. It was great.

Amy: Hopefully the technology Dr. Nestorova developed will allow NASA to more efficiently observe and analyze the plants grown on the ISS, so that space farming can progress and astronauts can build a sustainable habitat for themselves on the moon and eventually on Mars. Maybe it will even happen in time for Dr. Nestorova's son to step foot on Mars.

Dr. Serena Auñón-Chancellor: So where are we headed by 2024? I hear Mars. Well, certainly the moon first, right? If we could get to the Mars by 2024, that would be fantastic. But, we're not ready for that yet. So, we've got to practice first. And we need to do it on a place that's close three days away, allows us to learn how to build habitats, test engineering, design, grow food, protect the human. We need to practice all of this before we head to that big red planet. Because that is a long journey. That is a six to nine-month journey. So, you want to be as prepared as possible before you head in that direction.

Dr. Serena Auñón-Chancellor: So, Vice President Pence, of course, Space Policy directive one said we're going to land the first woman and the next man on the moon by 2024. But a lot of folks want to know, 'Well, why are we going back to the moon. We've been there, we've done that.' No, there's a very good reason we go back to the moon, because we are not ready to go to Mars. And we have to develop these technologies before we head out there.

Dr. Serena Auñón-Chancellor: So, thank you very much for having me. (clapping)

Amy: Thank you so much for listening to this special episode of Beyond 1894. Beyond 1894 is produced by the Office of University Communications, with help from The Waggoner Center and The School of Music, at Louisiana Tech University.

Amy: Dave Norris is the executive producer, and I, Amy Bell, am the producer and chief editor. To find our webpage, go to 1894.latech.edu/podcast.