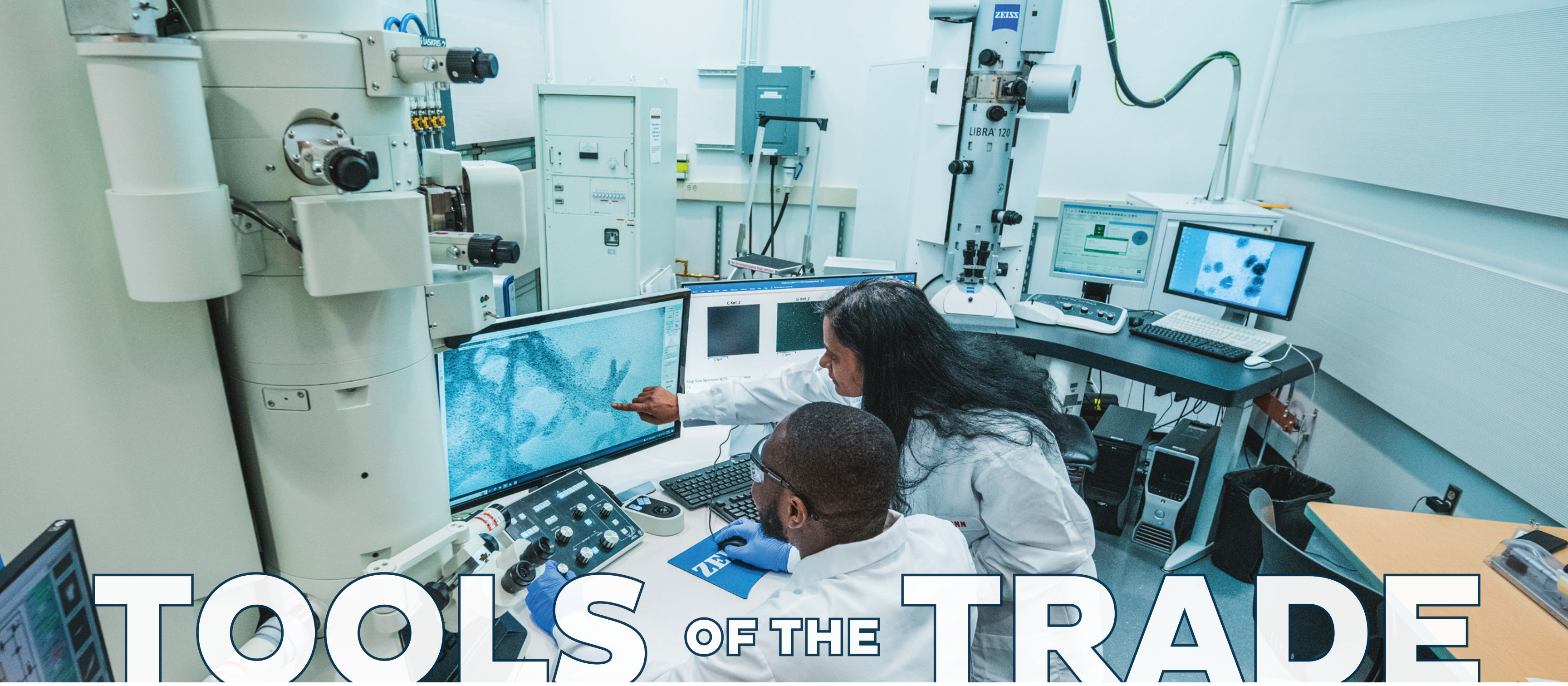
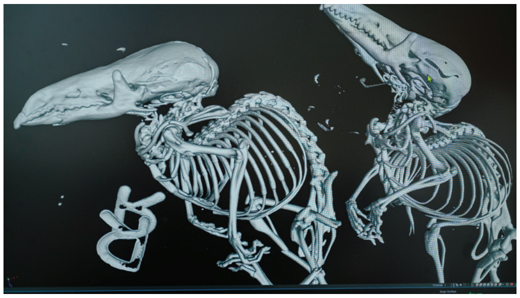
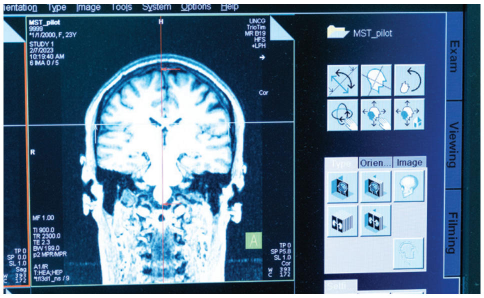
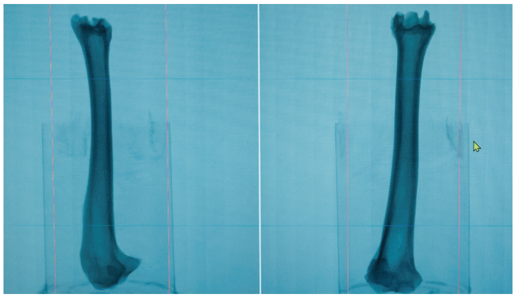



# TOOLS OF THE TRADE





Observation has always been fundamental to research – in the field or in a tightly controlled lab.

At the Joint School of Nanoscience and Nanoengineering, or JSNN, millions of dollars' worth of major scientific instruments are allowing faculty and students from across two universities to drive their scholarly projects forward with powerful, precise observation.

"Just for them to have access to these facilities, it enables us to move the research quicker," says JSNN Dean Sherine Obare. It also facilitates collaborations. "Easily a fourth of the usage comes from industry partners."

Among the major scientific instrumentation that now lives at JSNN are an MRI, a micro-CT scanner, and electron microscopes – including one that allows researchers to see objects as small as a single atom.

The multiple instruments together can give researchers a more complete view. "I need all that information together to really map out exactly what's going on," Dr. Obare says.

Without those instruments, researchers in kinesiology, anthropology, biology, nanoscience, and other fields would have to drive to other universities and pay hundreds of dollars per hour for access to equipment or try to negotiate access from busy hospitals.

"Even when researchers get access to those instruments, the time is restricted due to demand," UNCG's Vice Chancellor for Research and Engagement Terri Shelton notes. "You might only be able to get access late at night. Logistics like those can make it difficult to recruit research subjects and are disruptive for researchers and their students."

The presence of these scientific instruments makes UNCG a more attractive destination when Obare and other leaders are recruiting new faculty and graduate students.

"The fact that we have these facilities at the Joint School opens doors for us to attract really high-quality faculty because they know that what they need is going to be in the building," Obare says. "And faculty who are on the main campus at UNCG know they can just hop in the car and go three miles down the road – it means that they're going to be able to easily get data."

Students from UNCG and NC A&T – especially graduate students who may one day themselves be leading research labs at universities – get hands-on access to the equipment, facilitating their research and giving them the opportunity to develop expertise with the devices, Obare says.

"There's a humongous gap in knowledge, in terms of student training, when a student just takes a sample and sends that sample for analysis at a different location without being physically there," she says, "versus them actually preparing their sample and being able to image it themselves."

## SEEING THE INVISIBLE: HOW ANIMALS CHANGE OVER TIME

For the last few years, vertebrate paleontologist Robert Anemone would take fossils he was studying, drive more than an hour to Duke University, and pay $120 per hour for time on a micro-CT scanner.

Computerized tomography scanners, long used in medicine, have become a standard research tool for paleontologists and other scientists interested in the anatomical structure of plants and animals.

"It really has revolutionized paleontology," Dr. Anemone says.

A CT scanner works by taking thousands of x-rays of a fossil or bone sample at different angles. A computer knits together those images to create a precise, three-dimensional rendering.

That enables scientists like Anemone to precisely visualize, measure, and analyze skeletal structures. Sometimes, Anemone says, he doesn't even have to separate the fossil from the rock it's preserved within.

But driving to Duke ate up precious time and research funds.

Now, thanks to a $642,892 major instrumentation grant from the National Science Foundation, Anemone only has to drive from the UNCG main campus to the Joint School of Nanoscience and Nanotechnology, where he and other researchers have access to their own micro-CT scanner.

It was installed in March 2022. Anemone, JSNN's Obare, and biology faculty member Bryan McLean led the grant effort, which was successful in part due to its multidisciplinary focus.

"We've got the same machine they have at Duke University, just a much newer model," Anemone says. "It's been great for us, for our students. We've trained some of our students already in biology and anthropology to use the scanner here."

The machine is helping UNCG graduate students and faculty dig into important research questions and shed light on how animals interact with their environment, and how changes in their environment – whether across the change of seasons or over millions of years – affect animals.

By measuring different parts of a skeleton or analyzing marks left on bones and fossils, scientists can glean insights into the animal and the environment it lived in. How much and what kind of food was available? How did the animal move? How big was its brain?

By examining changes in animal morphology over millions of years and comparing those to other data about that time period, Anemone can learn how changes in the environment – such as climate change – affected animal species.

For example, around 55 million years ago, a period of warming birthed the earliest primates, with fossils found in Europe, Asia, and the North American Rocky Mountains. But then the climate cooled again and primates disappeared. "You don't find primates in the Rockies after 35 million years ago or so," Anemone says. "Global climate change is a dangerous thing – it leads to extinction and all sorts of unpredictable changes in biological communities."


### A 55-MILLION-YEAR-OLD DEER-LIKE MAMMAL

**Conducting fieldwork in Wyoming, Anemone's team discovered the most complete skull specimen of Esthonyx seen thus far. "Most of the time we find isolated teeth. An entire skull is a trove of information – brain size, nasal cavity, ear structure – giving us information on diet, how they balanced and moved, and more."**

Dr. Bryan McLean, the biologist, is interested in both evolutionary changes in mammals over long time periods, as well as short-term changes in individuals from one season to another.

He's studied how rodents around the world adapt in both similar and different ways to underground environments, including how their bodies change to allow them to dig. Some species use their forelimbs, some their hindlimbs, others make more use of their mouths.

"We're interested in the nuance that goes along with that," he says. "The extent to which there's trade-offs – the forelimb becomes enlarged, the other limbs aren't." By studying the animals' anatomy, he hopes to gain insights into how the environment can shape evolution.

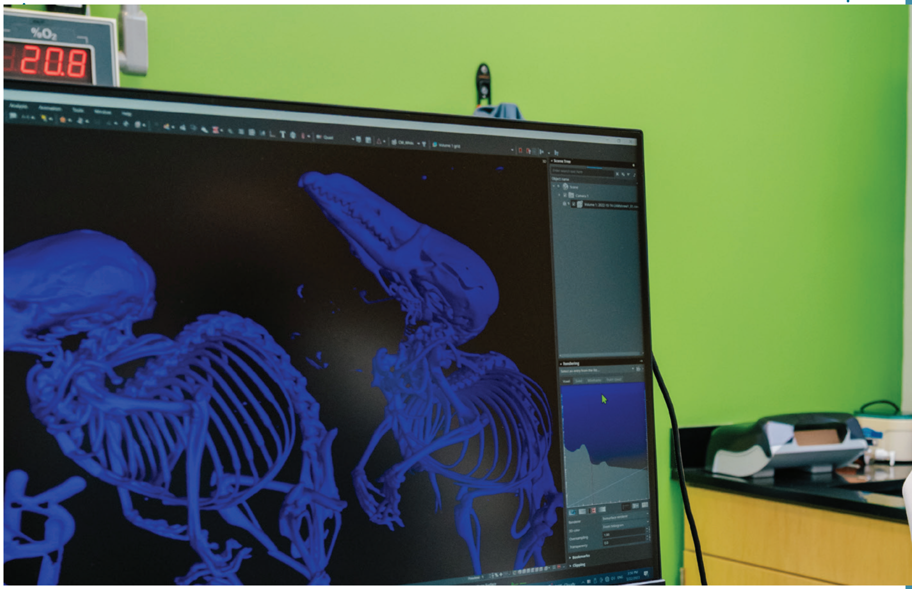
He's also interested in how short-term variations, such as changes in food availability and the weather, can prompt physiological changes – specifically, ones he can track through changes in anatomy. For example, he and his students collected mice from the Appalachian Mountains in North Carolina and discovered that during the winter, when food is scarce, their digestive tracts lengthened by about 35 percent. That should allow them to extract more nutrients from what food they are getting, McLean says.

Now, he and his students are measuring the skulls of Sorex shrews – a group of animals that includes dozens of species and subspecies in Europe, Asia, and North America. Research has shown that one European species will reabsorb part of its brain matter – resulting in smaller skulls – when food supplies shrink.

"We have more species in this one genus, Sorex, than exist in Europe, but the phenomenon has never been shown here," McLean says.

So, McLean and his students go to the western part of the state each season to trap shrews and bring them back to Greensboro for analysis. The micro-CT scanner allows them to create precise, detailed images of the animals' anatomy.

**SKULL SIZE IN RESPONSE TO FOOD SUPPLIES Undergrad researcher Leo Ivey and McLean gather data on shrew size, shape, and brain volume. The scanner means they don't have to clean, preserve, and then measure individual skeletons – something that could take years, McLean says. "It's speeding up what we can do."**




## INTO THE TISSUE: ACL AND THE BRAIN

UNCG researchers are using a magnetic resonance imaging machine, or MRI, to peer inside joints and take pictures of study volunteers' brains. Their goal is to better understand how our bodies and brains function – and why things go wrong – to find ways to prevent common problems.

"It never ceases to amaze me that here at UNCG we have access to this amazing tool to help us ask the questions that we really want to ask," says Randy Schmitz, professor of kinesiology and director of musculoskeletal imaging at the Gateway UNCG MRI Center, where the MRI is housed.

"This has torn down barriers," he says. "Our researchers no longer have to go to a medical institution here in town or another academic institution 60 miles away."

MRIs create high-resolution images of tissues that have water in them – virtually all tissues in the human body.

Powerful magnets in the machine cause protons in water molecules to align, and then the machine emits radio waves that tickle those water molecules. The water molecules give off energy the machine detects to create pictures of tissues. It can even measure blood flow in the brain.

Schmitz and Dr. Sandy Shultz, another kinesiology faculty member, use the machine in their study of anterior cruciate ligaments, which connect the thigh bone to the shin bone. ACL injuries are common in the United States among both athletes and nonathletes.

They are interested in figuring out why some people might be more prone to ACL injuries. Differences in knee and ACL structure could be the key, and might lead to better methods of injury prevention. Recently they patented a device to measure knee laxity – a strong predictor for future injury among young athletic females – across all three axes of motion.

Other researchers are using the MRI machine to investigate interactions between the brain and the body.

Dr. Jennifer Etnier, professor of kinesiology, is exploring how exercise may delay the onset of Alzheimer's. In one large research study with $3.4 million in National Institutes of Health funding, she recruited middle-aged and older adults who may have a genetic risk of Alzheimer's disease.

MRI scans of the volunteers' brains are one of the ways Etnier is assessing the impact of exercise on the volunteers' Alzheimer's risk. Among people with the highest genetic predisposition for Alzheimer's, brain changes can be detected as early as in someone's 40s. Etnier hopes to be able to assess whether exercise delays those harmful changes in brain structure.

Psychology faculty member Brittany Cassidy has used the MRI to study what parts of the brain are involved in different activities involving learning and memory.

One study, for example, examined how connectivity in the brain's default network affects mnemonic discrimination — an important kind of memory we use in daily life.

"It is looking at whether you can distinguish existing memories from similar perceptual experiences," Dr. Cassidy says. "For example, on a table full of coffee mugs, how can you remember which one is yours when you get back from a coffee break?"

Cassidy, along with her undergraduate and graduate researchers, has also used the MRI to study why older adults tend to be more trusting of others than younger adults — especially when the other person behaves negatively. The MRI showed that during the learning process, different parts of older adults' brains were more active when learning about someone's reputation for trustworthiness, or lack thereof.

**DEVELOPING EXPERTISE** **"From the first day of my doctoral program, I was excited to use the MRI scanner," says Dr. Alexis Ganesh, pictured below with Etnier. Ganesh worked with UNCG's machine as a grad student and then postdoc.**


Brain-body connections are also the research focus of kinesiology's Derek Monroe. He's trying to better understand the physiological and neurological results of traumatic brain injuries

"After a head injury, you might assume that damage will be localized to brain areas near to where the impact occurred," Dr. Monroe says. But his studies, conducted across different sports and populations, hint at more widespread effects.

"In my preliminary findings, the processes that regulate our basic bodily functions seem to be affected. However, there is still a lot of work to be done for us to understand the when, why, and how."

Monroe and his collaborators combine MRI data with information from the field, such as symptom reports and impact data recorded by specialty mouthguards.

He's also interested in the benefits of exercise. "We're exploring how exercise can help brains recover from injury and how it contributes to general brain health across our lifespan."

Monroe, whose focus is on behavioral neuroscience, was drawn to UNCG in 2020 after a postdoc at the University of California-Irvine medical school.

"The MRI, the facility, the resources, and other faculty who were already users of the technology are a big reason why I got excited about the position here at UNCG," he says.

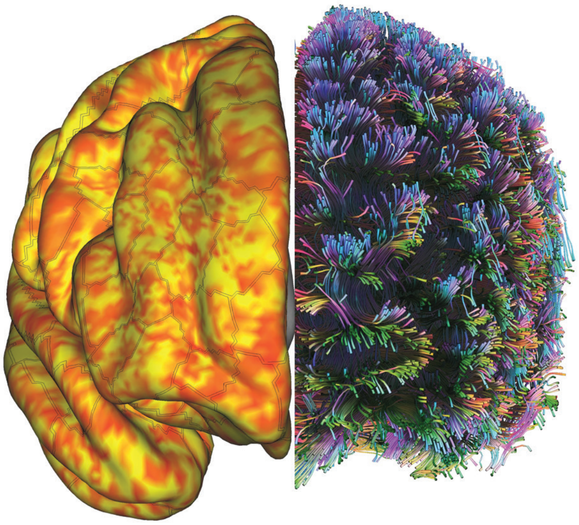
**GRADUATE TRAINING** **Monroe teaches students to use the MRI. To become proficient, they must learn about multiple disciplines, like physiology, physics, psychology, and data science.**

Monroe is also teaching students how to use the MRI machine. "I want to get graduate students now, and hopefully undergraduates in the near future, into courses – get them exposure to a machine that they would not have access to anywhere else," he says. "In the graduate course we spend two weeks, and we go over and we measure our brains. We then spend the second half of the course analyzing our brains."

Students learn how to upload the data and analyze it on powerful computers, and how to ask scientifically valid questions and understand the answers the MRI provides.

None of that, Monroe says, would be possible without both the equipment and a UNCG culture that encourages learning and interdisciplinary collaboration.

*"We're open for business. You can schedule here, you can scan here. Top to bottom, the support is incredible," says Monroe.*



**DATA ON STRUCTURE AND FUNCTION** **Monroe is interested in how exercise shapes the brain. For example, he and kinesiology's Dr. Donna Duffy have found that roller derby athletes at rest exhibit unique brain patterns. On the left is a map Monroe generated of the grey matter surface of a subject's brain. Areas in orange are functionally connected while the subject is in a resting state. On the right is a diagram of how deeper, white matter fibers connect different parts of the brain.**

## AT THE NANOSCALE

Atoms make up everything we can see – from one-celled organisms only visible under a microscope to miles-high mountains. But individual atoms and the complex structures they can form are too small to be seen by the naked eye, even under the most powerful optical microscopes.

That's a challenge for scientists like the JSNN's Dr. Hemali Rathnayake, who has devoted her career to studying and creating materials at the atomic scale.

To see, for example, openings that are big enough to let through some molecules but too small to let through others, she and her research collaborators use powerful microscopes that don't rely on light at all. Instead, they use beams of electrons.

Nanoscience is the study of objects and phenomena on the nanoscale, or one-billionth of a meter. For comparison, a sheet of paper is about 100,000 nanometers thick. Or, put another way, if the diameter of the earth was one meter, then one nanometer would be about the diameter of a marble.

"If we didn't have access to these electron microscopes, then actually most of our research would not move forward in the nanoscale," Rathnayake says. "We would be unable to do a lot of new science."

The JSNN's field emission scanning electron microscope, or FESEM, allows scientists and engineers to see structures down to 2 nanometers in size – smaller than the diameter of a strand of DNA. It allows researchers to see the surface of materials, Rathnayake says, and understand how that surface is structured: Are they crystals? How are they arranged?

The FESEM also enables scientists to examine the material's chemical composition to determine the elements comprising them.

Rathnayake won a $422,400 grant from the U.S. Department of Agriculture for the JSNN's FESEM, which was installed and operational in January of 2022. Another $599,000 grant from the Department of Defense funded the purchase of the transmission electron microscope, or TEM, installed in 2021.

The TEM projects a beam of electrons through a sample, allowing scientists to view the interior of a structure at an atomic scale. It allows for resolutions 10 times higher than the FESEM – down to about one-fifth of a nanometer, smaller than the diameter of a single atom of gold.

"That really opens up for us more capabilities to understand nanomaterials at, really, near atomic scale," Rathnayake says. Rathnayake's research is focused on developing nanomaterials that can protect and improve the environment. Her team has created, for example, specially designed materials that can capture lithium or other waste materials in water, allowing them to be recycled for commercial uses while also cleaning up the environment.

"I wanted to make the nanoworld more environmentally friendly, more sustainable, and nontoxic," she says. "If we are polluting the environment, we are not doing anything inventive."

Without these microscopes at the JSNN, Rathnayake would have to use NC State University's equipment. That makes the process of getting nanoscale images more time-consuming and expensive. It also reduces opportunities for UNCG students to get firsthand experience with the instruments.

"Joining UNCG was a clear choice for me as the university provided access to advanced instruments, such as FESEM and TEM, for studying materials at the nanoscale," says Kelvin Adrah, a PhD nanoscience student who works with Rathnayake (pictured above).

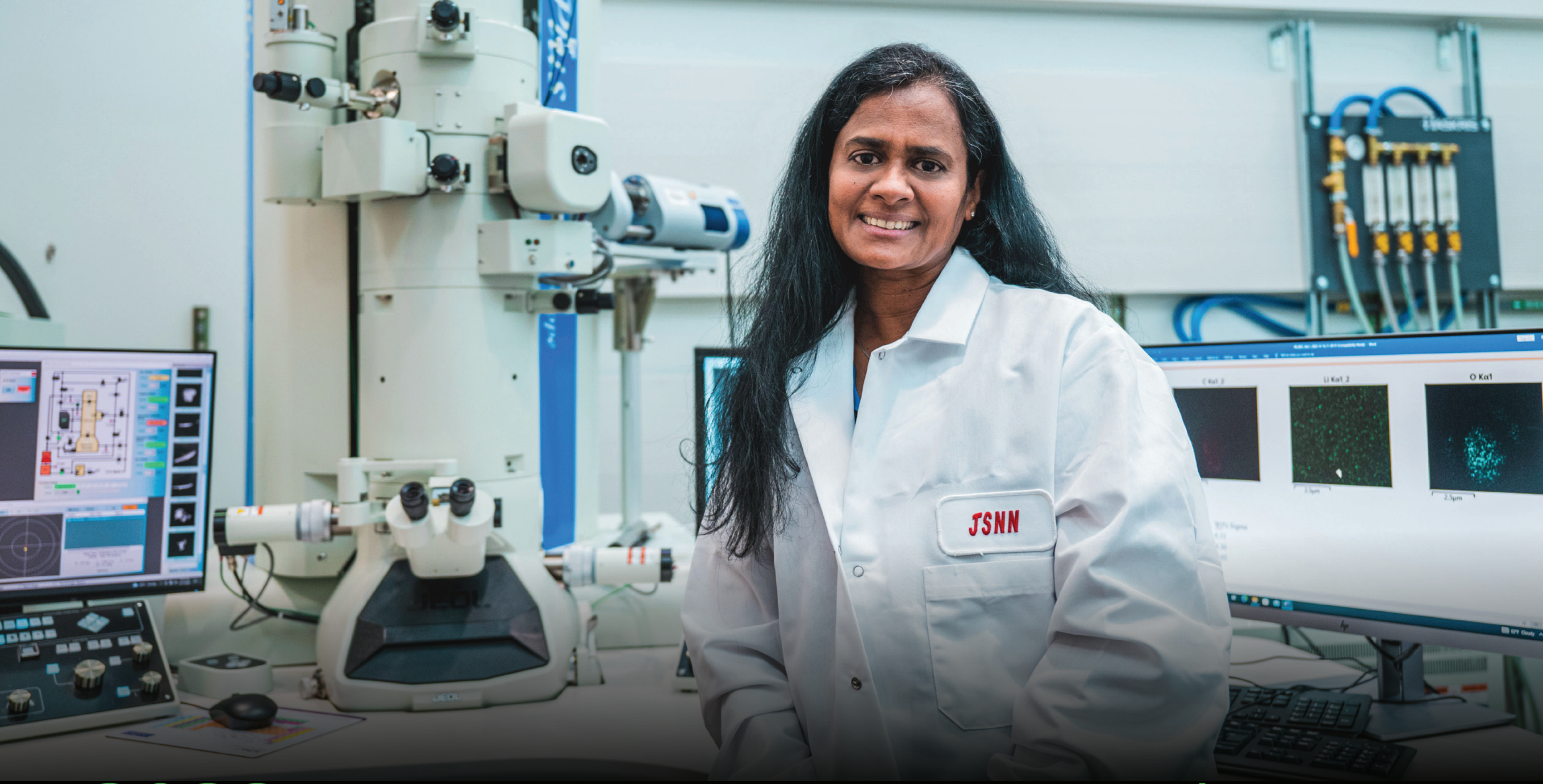
Having the FESEM and TEM on-campus provides UNCG students opportunities they wouldn't otherwise have, Rathnayake says. "They can become an expert on these instruments. Student training is a major reason we got this equipment."

Beneficiaries range from high school students in UNCG's Draelos Science Scholars Program to undergraduate researchers and graduate students – including those in the JSNN's recently launched 12-credit Nanoscience Certificate Program. "It's about growing the nanotechnology workforce," says Rathnayake.

Adrah, who entered the doctoral program to study materials that can be used for environmental remediation, has used both electron microscopes for his work. He says, "Having direct access to these instruments has been crucial for our research."

While the structures he studies are breathtakingly small, Adrah hopes that his education and research at JSNN will lead him to very visible rewards. "I aim to leverage my knowledge and contribute to the scientific community," he says, "ultimately entering industry to conduct research that benefits society."

*by Mark Tosczak • learn more at jsnn.ncat.uncg.edu*




# 2022 Research Excellence Award

*Dr. Hemali Rathnayake, associate professor of nanoscience, received UNCG's 2022 Early Career Research Excellence Award for her work on designing and making innovative nanomaterials that have the potential to build a greener, more sustainable future.*

*She's had more than 40 papers published in peer-reviewed journals, as well as several book chapters, and has been PI or co-PI on more than $1.7 million in grants at UNCG. She also co-founded UNCG spin-off company Minerva Lithium, which focuses on harvesting rare and technologically valuable minerals while simultaneously reducing water pollution.*

## ENVIRONMENTAL FOCUS

"At UNCG I've directed my research toward the design and manufacture of nanomaterials for environmental sustainability applications – energy harvesting, energy storage, water purification, and critical minerals. We've designed a series of novel nanomaterials. One can selectively extract critical minerals while also purifying wastewater. We also make nanomaterials that are biomolecules, which can self-assemble into very thin metal wires that you can use in the semiconductor industry for patterning transistors."

## GREEN CHEMISTRY

"There are a lot of harsh, toxic chemicals used to make nanomaterials. While we're making these nanomaterials to solve environmental problems, their production is actually toxic to the environment. My lab prefers to use green chemistry to avoid pollution.

"Green chemistry means most of the reactions are done with nontoxic solvents. You consume less energy for your reactions, and you do the chemistry at room temperature. There's much less toxic waste."

## COMMERCIAL POTENTIAL

"The nanomaterial we developed using agricultural waste makes a very environmentally friendly biomass-based nanomaterial. It can absorb the most important critical minerals that we use for batteries in electric vehicles – for example, lithium. We can make it cheaper and at room temperature, using minimal water. The commercial potential is huge. The economic impact that we can make is huge if we can solve the problem of directly extracting lithium from water resources."

## BECOMING AN ENTREPRENEUR

"I participated in UNCG's NSF-funded I-Corps training and advanced to the national level of the program. I learned a lot about thinking outside the box from a commercial perspective. I stepped in, took the risk, and I've learned a lot. It's paid off. Now I see the academic research point of view and the commercial point of view. I see myself as an academic entrepreneur."

## MENTORING STUDENTS

"I give them a small problem in the lab, and they try to solve it. During the first year I work with them in the lab training them. I help them understand the science behind the problem. Rather than teaching them the theory directly, I teach them scientific concepts through this hands-on approach. Building critical thinking – that's what I focus on. We need to make sure they're not technicians, that they become scientists."

*Interview by Mark Tosczak*