Researchers use IT to unlock the mysteries of human evolution

August 16 2016, by Katie Bohn

A femur, or thigh bone, waits to be scanned in the lab's microCT scanner. Credit: Katie Bohn

If you've ever seen a delivery truck driving around on campus, there's a small chance there could have been human bones nestled among its

cargo. Their destination? Penn State's Center for Quantitative Imaging, where a group of Penn State researchers are using 3-D imaging technology to study a variety of structures and materials, including bones.

Tim Ryan, associate professor of anthropology and information sciences and technology, is interested in what the inner structure of our bones can tell us about how we evolved as a species. He uses the center's microCT scanner to take 3-D images of bones and try to decipher why modern humans have such light skeletons.

Compared to our primate cousins, humans are a bunch of lightweights. Despite the fact that chimpanzees are typically smaller than humans, they have been estimated to be four times stronger than us. Our early ancestors, too, were more sturdily built. But somewhere along our evolutionary path, our bones have gotten lighter and less dense.

"Osteoporosis is a major health issue in contemporary humans," Ryan said. "Fossils suggest that when modern humans showed up around 200,000 years ago, we started seeing our skeletons become much lighter compared to earlier ancestors. I'm curious about what caused that shift."

Ryan hopes that learning more about how and why human bone density evolved might give scientists some insight into why people of European descent have greater instances of osteoporosis, among other questions.

"If we look at populations that have different behavioral patterns and different ancestral origins, then we can start to piece together what the baseline variation is within human bone structure," Ryan said. "Then, we can look at how that relates to osteoporosis in more modern populations."

The CT scanner stands in the middle of Penn State's Center for Quantitative Imaging. Credit: Katie Bohn

There are many theories about what caused our bones to become lighter. One guess is that changes in diet—less calcium from food and less vitamin D from the sun—caused the change. Another may be that as we gained more precise fine-motor skills, we also lost strength and bone mass. Ryan says he wants to look at how different behaviors and lifestyles could have contributed to this evolution.

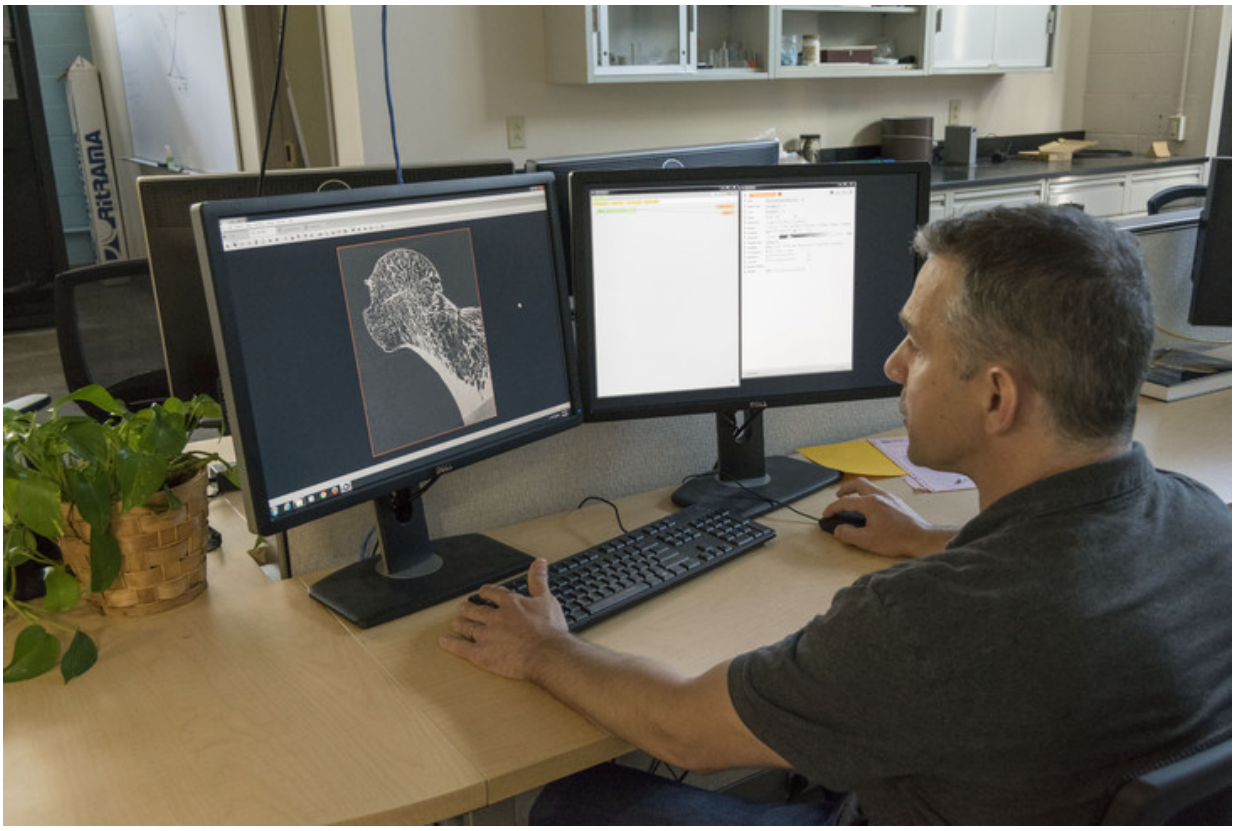
"In the past, humans had more physically demanding lifestyles. Hunter-gatherers, for example, were much more active and mobile than humans are now," said Ryan. "We want to look at how these different behaviors and lifestyles could have affected these changes in bone mass."

Ryan, along with a small team of undergraduate and graduate students, is using the lab's microCT scanning system to take 3-D images of trabecular bone—the inner, spongy layer of bone—from different human populations and then compare that data across individuals and groups.

Scanning human history

For some, anthropology might still stir up images of Jane Goodall and Dian Fossey spending years observing great apes in the jungle, hoping to glean some insight on evolution. But Simone Sukhdeo, who is currently pursuing her doctorate in anthropology while working in the lab with Ryan, says their research is less focused on observation and more technology-driven.

"Computers are part of every step of our work," Sukhdeo said, "from the initial data collection with the high-resolution scanner, to the computer programs we use to process, analyze and visualize the data."



Tim Ryan looks at a 3-D model of a bone that was created by using the lab's CT scanner. Credit: Katie Bohn

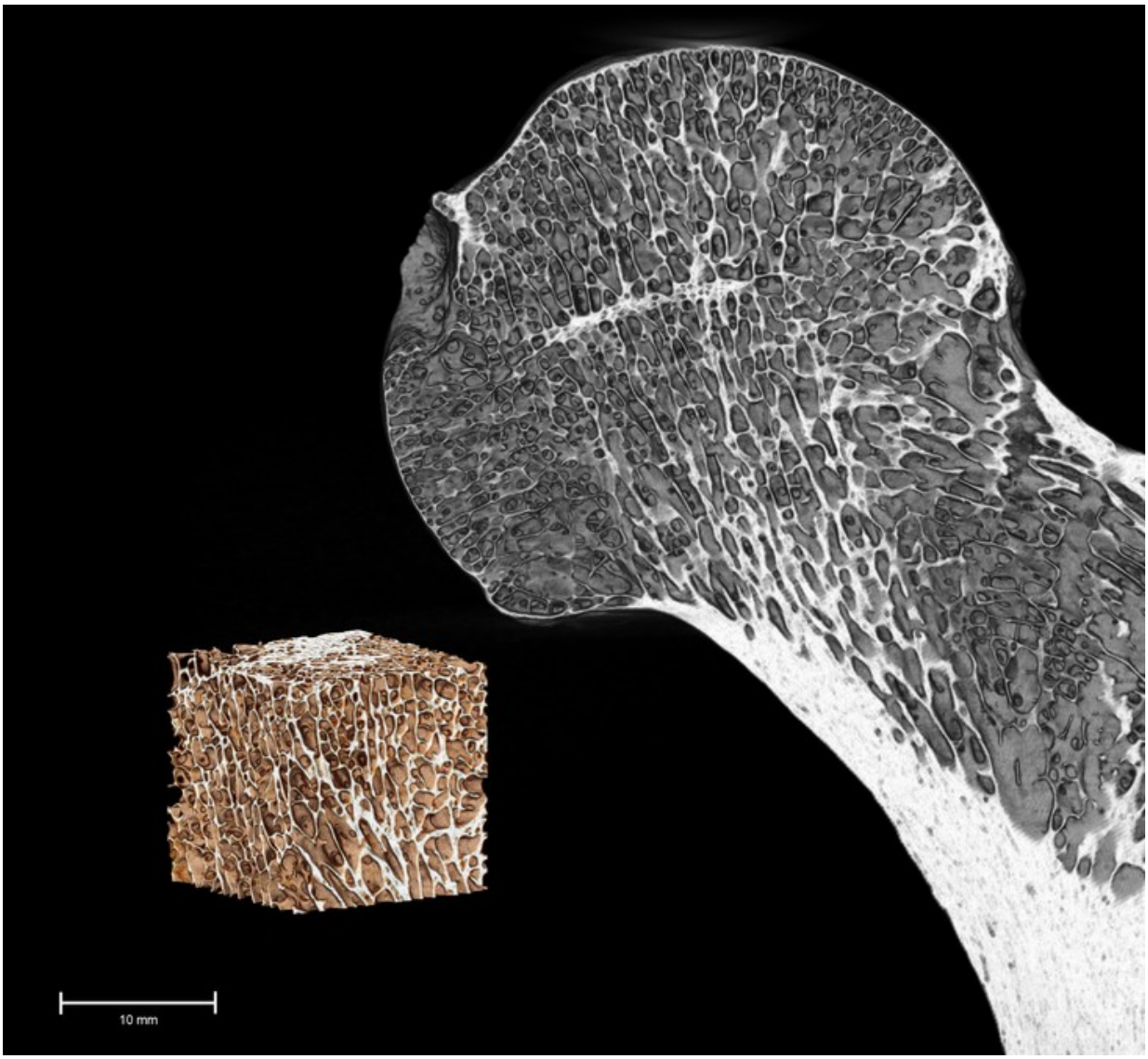
For their studies, Ryan and Sukhdeo are sometimes able to download CT images that have already been scanned by other institutions. Other times, collections of bones are loaned to the lab by museums or other universities so they can be scanned here at Penn State.

To scan a bone (or anything else), it must first be mounted securely in the scanner, which looms large in the middle of the lab. Depending on the size and shape of the object, this sometimes requires some finagling. A decently sized bone—like a femur or thigh bone, for example—might just need a plastic tube and some foam to keep it in place. But Ryan says smaller objects can be tougher.

"We've also scanned very small things, like tiny mice," said Ryan. "Those can be difficult because they have to be positioned just so, and they can't move at all or the images we collect will be useless."

Once the object is secured, the door is closed and the scan can begin inside the lead-shielded room. The instrument uses X-rays to capture a collection of 2-D projections of the object. When combined, the images form a series of 2-D "slices" that can then be used to construct 3-D digital models, allowing Ryan to gather data about the bone's structure and distribution.

In addition to providing precise high-resolution images, the technology gives the added bonus that the researchers don't have to actually saw into the bone to see its insides. It also ensures that the researchers will still have access to the data if something happens to the original object.



The center's microCT scanner makes it possible to create 3-D images like this one of a human femur. Credit: Tim Ryan

Comparing across populations

After the bones are scanned, Ryan and his labmates analyze and process the data using software like Avizio, ImageJ and MedTool.

"Once we have an image, then we have to digitally define it," Ryan said. "We'll decide on a section of the bone that we want to focus on and then use these software applications to measure features like the volume or distribution of the bone in 3-D space."

Ryan can then compare these data across human populations from different backgrounds and lifestyles. So far, they have data from about ten different populations, including hunter-gatherers and agriculturalists from North America, members of a more sedentary society from Sudan and Egypt, and people from the European Middle Ages.

"In the old days, you'd have to track down these specimens at different museums and actually go into the exhibit or the archives and take measurements using calipers, without seeing the inside of the bone," Ryan said. "Some anthropologists still do that, but it's not the approach we're taking. Here, we're using digital data to address our questions."

The scanner can take images of many objects, from bones to mice. Credit: Katie Bohn

Passing on a love of learning

In addition to his research, Ryan also teaches courses on evolution, morphology and 3-D imaging. He says that he hopes to give his students not just new anthropological knowledge, but also the skills to solve problems and questions of their own.

"At the end of the day, it's not about all the different species we can see in the fossil record," Ryan said. "It's about understanding how to address the questions of those species: What were they doing? What were they were eating? Then, how does that relate to what makes us human, and

what makes us unique—or not unique—from the other primates?"

For Sukhdeo, some of the questions she wants to answer are also some of life's hardest.

"Boiled down, anthropology is the study of man," Sukhdeo said. "What changes—both skeletally and behaviorally—occurred as we evolved from our common ancestor with the chimpanzee to modern humans today? Why are we alive, and how did we get here?"

As Sukhdeo works to finish her dissertation, which is exploring the evolution of the knee joint, she's starting to plan for what comes next for her after Penn State. While she says she's considering many options after she earns her doctorate, Sukhdeo says teaching is a definite possibility.

"We have many motivated and smart undergraduates in our lab. Watching them mature intellectually and discover their own passions is the best reward as a mentor," Sukhdeo said. "It's so cliché, but there is a moment when everything clicks and I love seeing that. It can happen on a small project or a thesis project, but that click makes it worth it. The hours, the work, the mental energy that graduate school can cost, it's given back two-fold when you get such rewarding experiences."

As for Ryan, he's staying hard at work in lab to help us learn more about why we are the way we are, one bone at a time.

Provided by Pennsylvania State University