MECHANICS OF MENISCUS

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Tammy Haut Donahue is an engineer on a mission. Her destination: to understand the mechanics of osteoarthritis—the degeneration of cartilage in joints, particularly the human knee.

Haut Donahue loves her work, which connects her to the world. "Knee problems are extremely common and debilitating. This research affects thousands of people and could potentially improve their lives. It's a very exciting field," says Haut Donahue.

Her research is centered on preventing the disease rather than treating it. She is specifically examining how injury to the meniscus, a fibrous cartilage in the knee, may cause osteoarthritis. This approach is uncommon and she can count on one hand the number of scientists nationwide who focus on the role the meniscus plays in osteoarthritic knees.

The meniscus acts as a buffer in the knee joint and is susceptible to injury, especially in athletes. Older adults are also at high risk, and aging baby boomers represent millions of potential patients who would be affected by this research. Haut Donahue hypothesizes that if scientists can prevent degenerative changes in the meniscus, they may be able to slow or halt the progression of osteoarthritis.

When walking or running the knee undergoes severe mechanical loading. The meniscus, which is a soft, crescent-shaped tissue, separates the contact areas of the knee joint. Dampening impact like a shock absorber, it has two functions: to distribute the mechanical load on the knee over the entire joint and to protect the cartilage that adheres to the end of each bone. The meniscus itself has no nerves and therefore produces no sensation. Without a meniscus, cartilage wears against cartilage. When the cartilage is worn away, bone wears on bone. Both are painful conditions. "This process of the cartilage wearing away is osteoarthritis," Haut Donahue says.

Haut Donahue grew up in Lower Michigan where she attended Michigan State University and later moved on to the University of California at Davis where she earned a Master's Degree in Mechanical Engineering and a PhD in Biomedical Engineering. She accepted a position at Michigan Tech in 2001, after conducting a year of postdoctoral work at Penn State.

Her research encompasses two disciplines: measuring the mechanical processes of impact and wear while tracking the biological responses to those events. She explains that a mechanical load induces a biochemical reaction in the meniscus. "It's a close relationship," she explains. "So close that one relies on the other. That is, mechanical loading keeps the cells of the meniscus healthy. It's the very nature of the tissue. We know if we take away loading, the tissue degrades."

The aim of Haut Donahue's research is to understand how the mechanical loading produces a biochemical response. "The tissue is constantly changing," she says.

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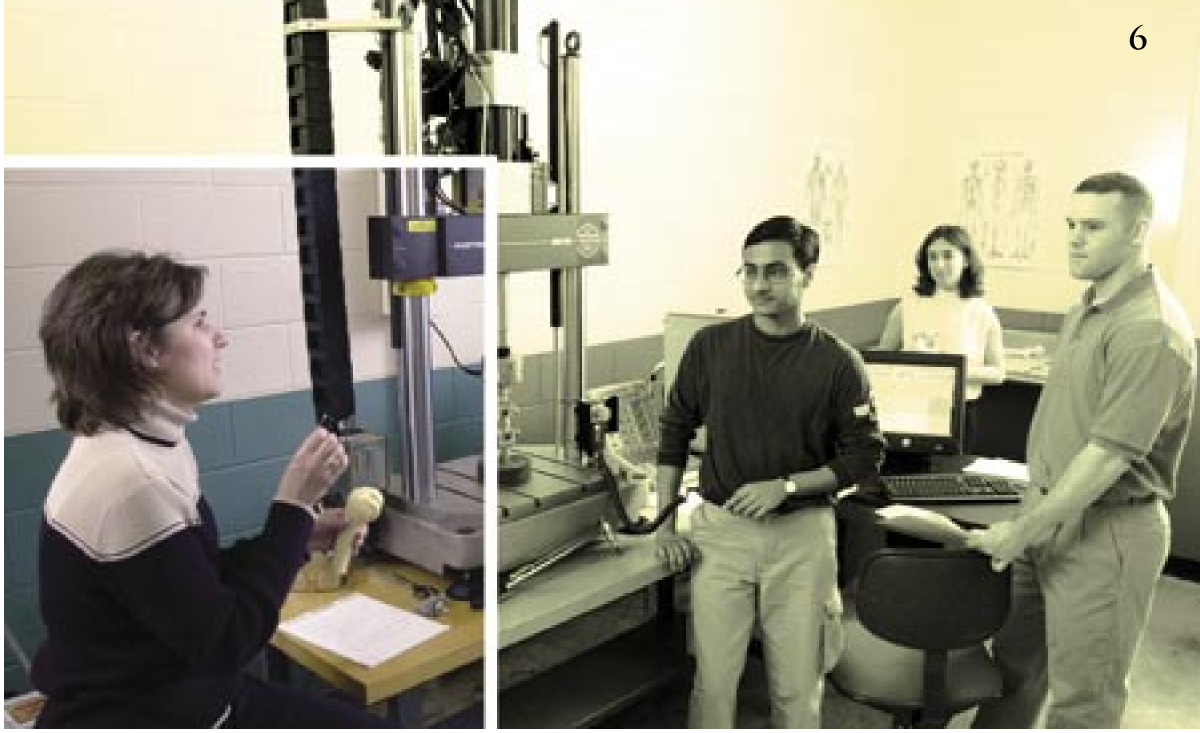

"You don't just make it and it sits there. Everyday tissue is changing. It's producing new matrix constantly. There's a remodeling process in the meniscus, and it relies on the loading. We want to know how loading causes the cells to have a biochemical output. It's a critical function to understand because the biochemical response produces healthy tissue, which can withstand greater mechanical loading. It's a cycle."

A damaged meniscus from either a sports injury or old age is treated by surgically removing the damaged tissue—a problematic practice that dates back to the 1940s. "We don't advise this treatment, but surgeons often choose it because there aren't many other options," she says.

Through her research, Haut Donahue is pursuing an alternative approach to the removal of damaged tissue. "Rather than having a surgeon go in and take torn tissue out, we want to repair it. We want to take a biopsy, bring it to the lab, apply the right mechanical loading to it, and thereby grow new tissue from the ground up." The process is called *tissue engineering*. "Hopefully, when this tissue is damaged, we can put in a sufficient replacement that behaves the same way as the normal tissue. The science isn't there yet, though. In order to design the new tissue, we have to understand very clearly how the original tissue functions," says Haut Donahue.

One approach that has not succeeded is synthetic prosthesis. Scientists have attempted to replace the meniscus with several synthetic materials such as metal, Dacron, and Gore-Tex. However, the geometry and material properties, the mechanics of the meniscus, are not something easily replicated with synthetic material.

Meniscus tissue is seventy percent water. "You'd never know it if you held it in your hand; it's a solid structure," Haut Donahue explains. The empirical understanding that mechanical loading allows the meniscus to continually reinvent itself has led her to test three possibilities: compression, fluid flow, and combination. It is possible that compression of the cells alone could induce the redevelopment of new, healthy cells. Alternately, fluid flow resulting from compression, or a combination of compression and flow could be required. "We're looking for the right signal," she says.

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The search has attracted a $240,000, three-year grant from the Whitaker Foundation. Haut Donahue's research team includes seven graduate students and four undergraduate students. Some of the work is theory; some computer modeling; and some of it uses animal models to investigate the process. It's all groundbreaking work. "The rest of the United States," she says, "studies what happens to bone and cartilage in the absence of meniscus. My goal is to protect the cartilage and interrupt osteoarthritis before it starts. Then you won't have the arthritis problem in the first place, " she said.

There are thousands of researchers focused on bone and cartilage only, but very few others are working on the meniscus. The cells in the meniscus are one-fifth the diameter of a strand of human hair. "That makes it tough to measure the mechanical loading experienced by a single cell," says Haut Donahue.

Her immediate goal is to understand how the meniscus works. In ten years, she hopes to accomplish tissue engineering or as she describes it, "Building a scaffold that will mimic your natural tissue." With a lifetime goal to prevent osteoarthritis in the knee, Haut Donahue remains focused on her mission and developing her team. "I see tremendous possibilities for this research."