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One Step at a Time: Robotics Lab Team Combines Talents in Quest for the Perfect Synthetic Tendon

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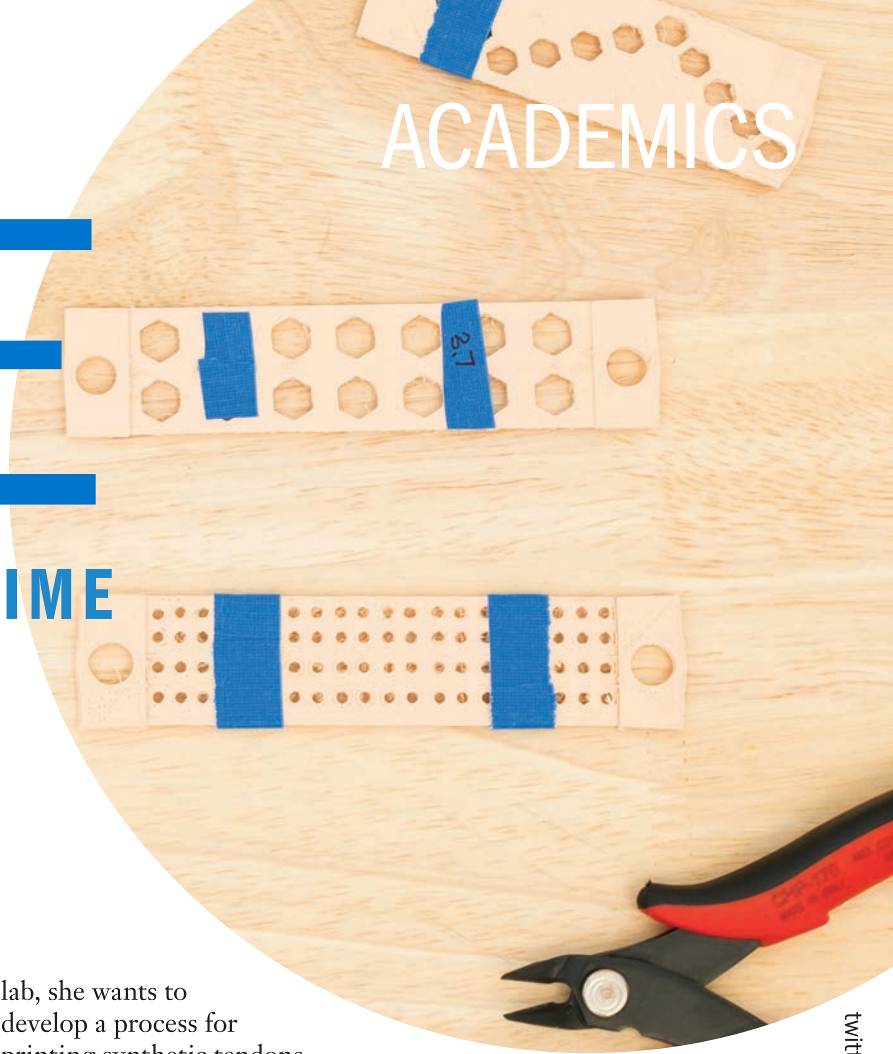

ONE STEP AT A TIME

By Laura Meader

ROBOTICS LAB TEAM COMBINES TALENTS IN QUEST FOR THE PERFECT SYNTHETIC TENDON

When Caitrin Eaton arrived at Colby a year ago, she named her new robotics lab C3PO. The name grabs students' attention, but they're drawn to the lab for another reason: Eaton's cutting-edge research unites engineering and animal physiology to help robots walk more smoothly than Hollywood's stiff-legged C-3PO robot.

"Animals that we don't think of as highly intelligent can walk," Eaton said. "Mice can walk quite well. Cockroaches can walk. By looking at what's working in biology we can learn about how we make this an easier problem for robots."

What's needed? "Squishy parts," says Eaton, referring to cartilage and tendons abundant in animals.

Last summer Eaton, assistant professor of computer science, hired three students to collaborate with her in the Colby College Computational Physiology and Optimization Lab (C3PO) to make and test those parts—specifically three-dimensional synthetic tendons.

Eaton, who did her doctoral research as the University of South Florida, isn't the first roboticist to consider using pliable materials in robotic joints. (Springs were added to legged robots in the 1980s, and many robots today use tendon-like structures.) "We know tendons are useful," Eaton stated. "But how do we choose a good one?"

During graduate school—writing computer programs to control pliable materials in robotic simulations—and her post-doc in a muscle physiology lab, Eaton gained an understanding of the ways compliant materials—including muscle and cartilage—affect locomotion. Now with her own lab, she wants to develop a process for printing synthetic tendons with predetermined stiffness, she said, and study their effects on the energy efficiency and stability of a robotic limb.

Tendons—cords that attach muscle to bone—allow for smooth and efficient locomotion by recycling mechanical energy, amplifying muscular power, and safeguarding muscles under sudden loads. Tendons complete these tasks passively, without active input from the brain.

The C3PO lab gave Eaton freedom to take her first steps in designing tendons. She had never done 3D printing before nor had she supervised students. She wasn't sure how much they could accomplish in 10 weeks of summer research, but she soon discovered the "insane amount of potential" the students brought to the project.

And for the students—Heejoon Ahn '19, Riley Karp '19, and Trisha Ramdhoni '21—it was an exciting opportunity to conduct real-world computational biology research as undergraduates.

Ramdhoni, a computational biology and mathematical science double major from Mauritius, used FreeCAD—an open-source modeling software—to design the tendons and a 3D printer to create them. The printer uses plastic filament (instead of ink) laid down in layers in lattice-like patterns. By varying the patterns (squares, circles, or none) and their thickness (1-3 mm), Ramdhoni created tendons of a constant width and length but with varying densities.

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> **It was a great experience that allowed me to understand what comp bio really is. I fell in love with it.”**
>
> **—Heejoon Ahn ’19**

Determining each tendon’s stiffness fell to Karp, a computer science major from Plymouth, N.H. She designed an experimental setup that included figuring out how to attach each end of the tendon to an instrument called a force gauge. Karp used the webcam on her laptop and a program she wrote to track blue tape adhered to each end of the tendon to measure how much it stretched under controlled tension. With this, she was able to calculate each tendon’s stretchiness using the equation stiffness equals force divided by change in length.

The team printed and tested approximately 50 tendons during the summer (each tendon takes 7-9 hours to print), learning how to use and control the plastic filament and amassing enough data to write a program that will predict the stiffness of a printed tendon.

At the same time, Ahn was studying microscopic protein filaments in muscles called sarcomeres that slide together and connect when muscles contract. The connections generate force in the muscle. Ahn, a computational biology major from the Seattle area, compared lengths of the filaments in different organisms (crayfish, vertebrates, octopi) to see how they influence force and energy in muscles.

“The middle ground between the two projects,” Eaton explained, “is like when you have muscle and a tendon in series—how do they interact?” By better understanding animal physiology, better robots can be built. “Things in biology have been pretty well stress tested for performance. So it makes sense to use that as a seed for a search.”

Both projects have the end goal of creating user interfaces for researchers and biologists that would take in parameters (weight, mass, length) and output values for tendon design.

“If I were going to design a robot and I know how much I’m expecting it to weigh, I might want to look at something similar on the biological scale,” Eaton said. “If I’m expecting it to weigh about as much as a golden retriever, I probably don’t need an elephant tendon or a cockroach tendon.”

By summer’s end, the team had progressed far enough to write an extended abstract, “Exploring structural control of stiffness in synthetic tendon,” that they submitted to the IROS (Intelligent Robots and Systems) Conference in Madrid. The abstract wasn’t accepted, but they’re not giving up. They’re back in the lab continuing their research with plans to submit a full-length conference paper when they’ve completed testing tensile strength (the force at which the tendon will break) and a journal article when they have a functional limb, Eaton said.

Ten weeks of research transformed the team. The project allowed Ahn, with knowledge of computer science, biology, chemistry, and biochemistry, to blend her interests. “It was a great experience that allowed me to understand what comp bio really is,” she reflected. “I fell in love with it.”

Karp said that the project helped her figure out which part of biomedical engineering she wants to do at Dartmouth, where she’ll return next year to complete her dual-degree program. Her interest lies in working with real tissue, and the exposure to synthetic tissue solidified that interest.

Being part of such a motivated team was a bonus for Ramdhoni, who was also excited to write her first real paper, not just one for a class, she said. Coming on the heels of her first year at Colby, she said the research “broadened my horizons and got me thinking about what I’m going to do as a career.”

Eaton was dazzled by the students’ ability to take an idea and run with it. “Giving them a piece of the puzzle and seeing what they do with it has been pretty cool,” she said. As Eaton begins her second year at Colby, her C3PO is up and running.