# Light-activated skeletal muscle engineered (w/ Video)

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Many robotic designs take nature as their muse: sticking to walls like geckos, swimming through water like tuna, sprinting across terrain like cheetahs. Such designs borrow properties from nature, using engineered materials and hardware to mimic animals' behavior.

Now, scientists at MIT and the University of Pennsylvania are taking more than inspiration from nature—they're taking ingredients. The group has genetically engineered muscle cells to flex in response to light, and is using the light-sensitive tissue to build highly articulated robots. This "bio-integrated" approach, as they call it, may one day enable robotic animals that move with the strength and flexibility of their living counterparts.

The researchers' approach will appear in the journal *Lab on a Chip*.

Harry Asada, the Ford Professor of Engineering in MIT's Department of Mechanical Engineering, says the group's design effectively blurs the boundary between nature and machines.

"With bio-inspired designs, biology is a metaphor, and robotics is the tool to make it happen," says Asada, who is a co-author on the paper. "With bio-integrated designs, biology provides the materials, not just the metaphor. This is a new direction we're pushing in biorobotics."

## Seeing the light

Asada and MIT postdoc Mahmut Selman Sakar collaborated with Roger Kamm, the Cecil and Ida Green Distinguished Professor of Biological and Mechanical Engineering, to develop the new approach. In deciding which bodily tissue to use in their robotic design, the researchers set upon skeletal muscle—a stronger, more powerful tissue than cardiac or smooth muscle. But unlike cardiac tissue, which beats involuntarily, skeletal muscles—those involved in running, walking and other physical motions—need external stimuli to flex.

Normally, neurons act to excite muscles, sending electrical impulses that cause a muscle to contract. In the lab, researchers have employed electrodes to stimulate muscle fibers with small amounts of current. But Asada says such a technique, while effective, is unwieldy. Moreover, he says, electrodes, along with their power supply, would likely bog down a small robot.

Instead, Asada and his colleagues looked to a relatively new field called optogenetics, invented in 2005 by MIT's Ed Boyden and Karl Deisseroth from Stanford University, who genetically modified neurons to respond to short laser pulses. Since then, researchers have used the technique to stimulate cardiac cells to twitch.

Asada's team looked for ways to do the same with skeletal muscle cells. The researchers cultured such cells, or myoblasts, genetically modifying them to express a light-activated protein. The group fused myoblasts into long muscle fibers, then shone 20-millisecond pulses of blue light into the dish. They found that the genetically altered fibers responded in spatially specific ways: Small beams of light shone on just one fiber caused only that fiber to contract, while larger beams covering multiple fibers stimulated all those fibers to contract.

## A light workout

The group is the first to successfully stimulate skeletal muscle using light, providing a new "wireless" way to control muscles. Going a step further, Asada grew muscle fibers with a mixture of hydrogel to form a 3-D muscle tissue, and again stimulated the tissue with light—finding that the 3-D muscle responded in much the same way as individual muscle fibers, bending and twisting in areas exposed to beams of light.

The researchers tested the strength of the engineered tissue using a small micromechanical chip—designed by Christopher Chen at Penn—that contains multiple wells, each housing two flexible posts. The group attached muscle strips to each post, then stimulated the tissue with light. As the muscle contracts, it pulls the posts inward; because the stiffness of each post is known, the group can calculate the muscle's force using each post's bent angle.

Asada says the device also serves as a training center for engineered muscle, providing a workout of sorts to strengthen the tissue. "Like bedridden people, its muscle tone goes down very quickly without exercise," Asada says.

The light-sensitive muscle tissue exhibits a wide range of motions, which may enable highly articulated, flexible robots—a goal the group is now working toward. One potential robotic device may involve endoscopy, a procedure in which a camera is threaded through the body to illuminate tissue or organs. Asada says a robot made of light-sensitive muscle may be small and nimble enough to navigate tight spaces—even within the body's vasculature. While it will be some time before such a device can be engineered, Asada says the group's results are a promising start.

"We can put 10 degrees of freedom in a limited space, less than one millimeter," Asada says. "There's no actuator that can do that kind of job right now."

Rashid Bashir, a professor of electrical and computer engineering and bioengineering at the University of Illinois at Urbana-Champaign, says the group's light-activated muscle may have multiple applications in robotics, medical devices, navigation and locomotion. He says exploring these applications would mean the researchers would first have to address a few hurdles. "Development of ways to increase the forces of contraction and being able to scale up the size of the muscle fibers would be very useful for future applications," Bashir says.

In the meantime, there may be a more immediate application for both the engineered muscles and the microchip: Asada says the setup may be used to screen drugs for motor-related diseases. Scientists may grow light-sensitive muscle strips in multiple wells, and monitor their reaction—and the force of their contractions—in response to various drugs.

The other authors on the paper are Devin Neal, Yinqing Li and Ron Weiss from MIT, and Thomas Boudou and Michael Borochin from Penn.

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