phase could provide durable prevention of B-cell autoantigen presentation. Thus, CAAR T cells that selectively target pathogenic autoantigen-presenting B cells could be advantageous over CD20-specific antibodies that deplete all B lymphocytes independently of their fine specificity.

We are at an important crossroads where advances in biotech give us a glimpse of the possibility of providing a real cure for autoimmune diseases in a not-too-distant future.

COMPETING FINANCIAL INTERESTS

The author declares no competing financial interests.

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Alighting on soft robot rays

Imagine robots more like animals than machines. This is the goal of the field of soft robots, which aims to build robots with soft materials, sometimes powered by living muscle tissue or cells. A recent paper by Park *et al.*[1] describes the design and construction of a soft robot that mimics the swimming motion of a ray fish. Powered by optogenetically engineered cardiomyocytes layered on a polymer body, the robot follows light and maneuvers through an obstacle course.

"At this point, there aren't design tools that tell us how to build a soft robot to simulate the movements and behaviors of biological systems," says Bradley Nelson, a professor of robotics at the Swiss Federal Institute of Technology in Zurich, Switzerland. "We don't have a general understanding of how to optimally integrate various material properties in order to perform complex functions," he adds.

The idea of simulating features from animals, from jellyfish to snakes to cheetahs, to learn these lessons, is not new. Batoid fish—shark relatives that include rays and skates—are good candidates for soft robot efforts because they have an energy-efficient undulatory movement. The fish, characterized by their flattened body, have pectoral fins, which they use asymmetrically and independently for fine movement.

To mimic this in a robotic ray, Park *et al.*[1] make a body of layered elastomers powered by rat cardiomyocytes. The researchers engineered these cells to express a light-sensitive ion channel, channelrhodopsin-2, as a means of triggering muscle contraction. The myocytes, which use glucose in the medium for energy, are arranged in serpentine-patterned circuits, enabling the propagation of the muscle contraction through the body of the robot. The myocytes on each side of the body respond to different light frequencies, allowing the fins to be independently actuated, as in the fish. The resultant tissue-engineered robot was capable of following light and avoiding obstacles. It travelled a distance 15 times longer than its body length and maintained 80% of its initial speed for 6 consecutive days.

The ray is only about one-tenth the size of the fish it resembles and cannot move through turbulent waters, but combining elements that have been used for other purposes in a system with this behavior is a considerable accomplishment. "It's a very clever and simple way to model functionality," says Gordana Vunjak-Novakovic, a professor of biomedical engineering at Columbia University Medical Center in New York. "The approach incorporates only as much complexity as it needs," she says.

The lessons learned from simplifying the biology while recapitulating the swimming of the fish are valuable for engineers as well as biologists. "The robot serves as a controlled system in which to study the motion," says Vunjak-Novakov. These studies can help us understand why animals evolve the way they do and uncover advantages of specific aspects of animal physiology. From an engineering standpoint, "there are things we can do that nature simply cannot do," says Nelson.

Combining engineering principles and materials with lessons from nature could be powerful. "An obvious application is targeted therapy: if they were small enough, robots could be targeted to specific parts of the body," says Nelson. In the near-term, "you can also imagine that devices that move through water could enable environmental clean-up, homing in to the affected area and maybe catalyzing toxins," he adds. The ultimate goal, he says, would be to create small devices that have autonomous behavior: "they themselves have sensing and actuation as well as computation so they can do something useful on their own." The potential biodegradability of such soft robots would represent an additional advantage.

Creating soft robots that can perform real-world tasks outside of the laboratory, though possible in principle, is not a trivial problem, says Vunjak-Novakov. Much of the work on soft robots remains at the proof-of-principle level. Such issues as low-force outputs, sensitivity to variation in environmental conditions, and a paucity of options to generate and store power in such robots represent ongoing challenges. But, as she points out, "nature is beautiful, there are so many different structures that are built for function." If we continue to construct devices that can model them, we may learn enough to one day make the soft robots we need most.

Irene Jarchum, Associate Editor, Nature Biotechnology

[1] Park, S.-J. *et al. Science* **353**, 158–162 (2016).