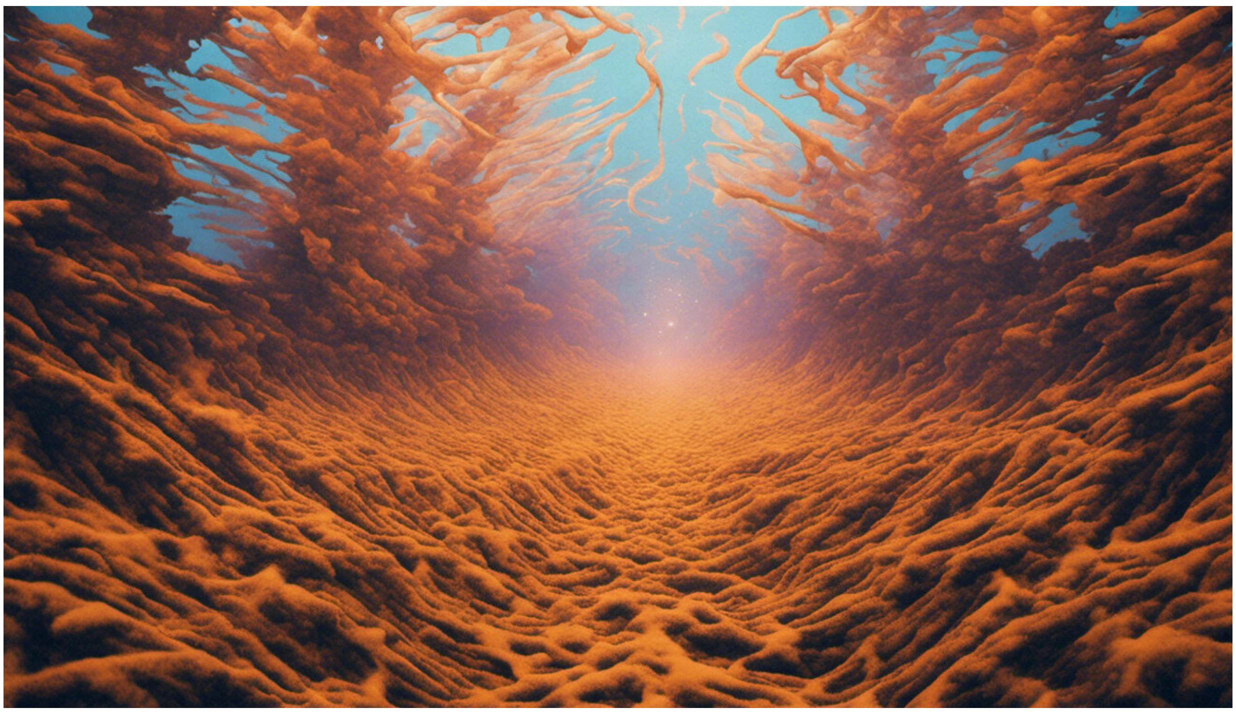
Breakthrough creates tough material able to stretch, heal and defend itself

February 4 2020, by Louise Lerner



Credit: AI-generated image (disclaimer)

While eating takeout one day, University of Chicago scientists Bozhi Tian and Yin Fang started thinking about the noodles—specifically, their elasticity. A specialty of Xi'an, Tian's hometown in China, is wheat noodles stretched by hand until they become chewy—strong and elastic. Why, the two materials scientists wondered, didn't they get thin and weak instead?

They started experimenting, ordering pounds and pounds of noodles from the restaurant. "They got very suspicious," Fang said. "I think they thought we wanted to steal their secrets to open a rival restaurant."

But what they were preparing was a recipe for synthetic tissue—that could much more closely mimic biological skin and tissue than existing technology.

"It turns out that granules of common starch can be the missing ingredient for a composite that mimics many of the properties of tissue," said Fang, a UChicago postdoctoral researcher and lead author of a new paper published Jan. 29 in the journal *Matter*. "We think this could fundamentally change the way we can make tissue-like materials."

The breakthrough allows the synthetic tissue to stretch in multiple directions but to heal and defend itself by reorganizing its internal structures —which is how human skin protects itself. The discovery could one day lead to applications from soft robotics and medical implants to sustainable food packaging and biofiltration.

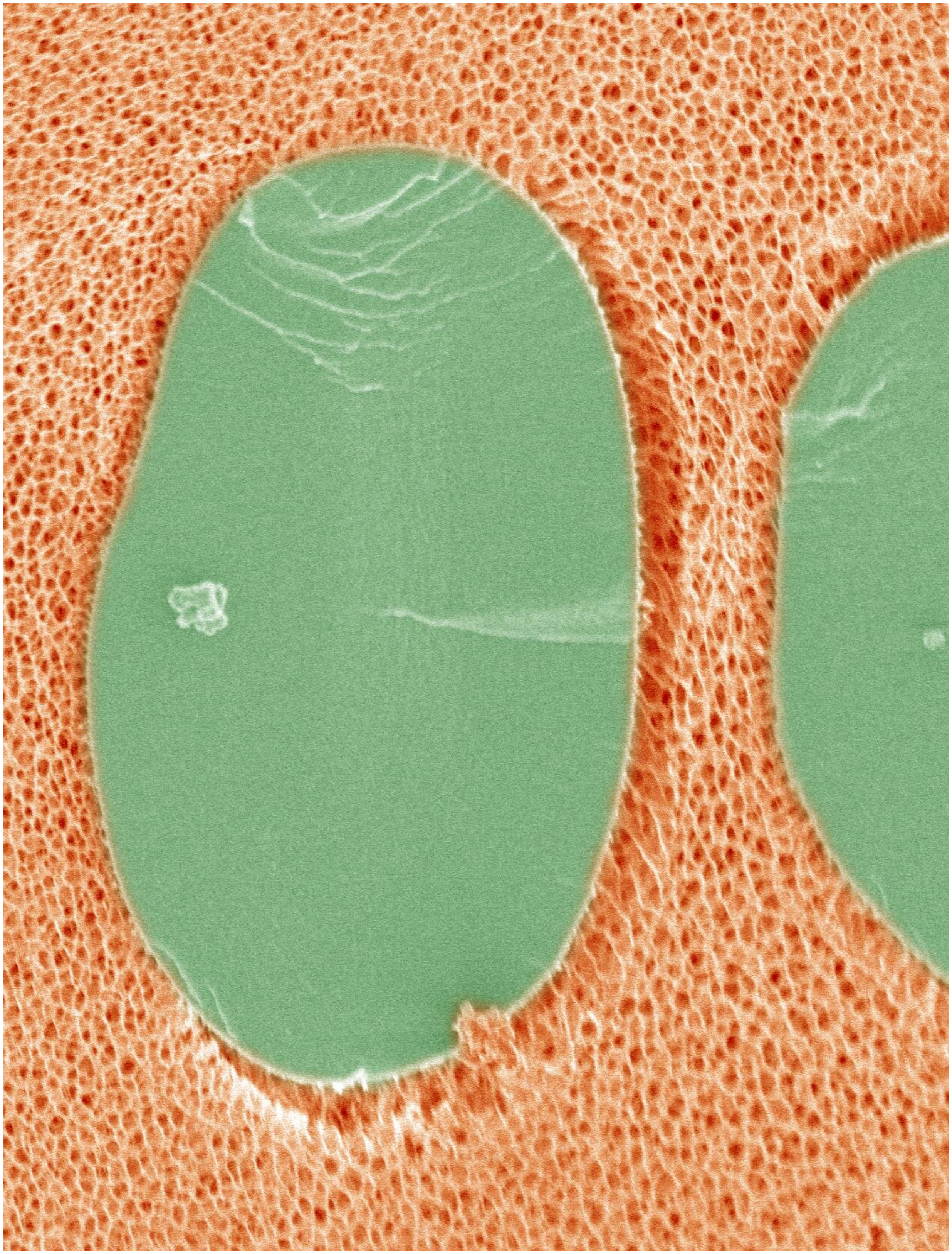
Like many of nature's inventions, skin and tissue are extraordinary feats of engineering that have been difficult for humans to mimic. Tian is a leading investigator in this area, confronting this problem by seeking to build interfaces between biological tissues and man-made systems.

Most current options for synthetic tissues can only manage one or two of biological tissue's characteristics: malleability but not strength, or strength but not self-healing.

Experimenting on the noodles, the scientists found that the internal structure consisted of a gluten network studded with granules of starch.

"It actually looked a lot like biological tissue," Fang said, "because tissue consists of an extracellular matrix that supports individual cells."

Synthetic tissue is usually made of a gel mesh, which mimics the structure of the extracellular matrix—but doesn't contain an analogue for the cells. But the scientists wondered: What if the cells were an important component of the tissue mechanics?



An electron microscope image of the starch granules (green) embedded in the hydrogel matrix. Credit: Tian, Fang et al

Tian and Fang's idea, was to embed granules of starch into a gel matrix, thinking that this would change the way the material moved.

It did. The "tissue" was not only strong and flexible, but it changed after it had been stretched—much like what happens when you train your muscles. "This 'memory effect' in particular is extremely difficult to replicate synthetically," said Tian, who is an associate professor in the Department of Chemistry.

The crucial difference is the presence of the starch granules. They can shift slightly in place when the material is strained, and their ability to move constantly modifies the internal structure —allowing the "tissue" to deform when it might otherwise break.

Their hydrogen bonds, which can re-form after being broken, also allow the material to heal itself. "As long as they're still in physical contact, those bonds will eventually re-form," Yin said.

The concept offers possibilities for a number of applications. Fang in particular is interested in using the material for food packaging. Oranges or bananas have peels that are made up of a similar matrix that absorbs impact when they're bouncing around in a truck, but other foods don't—and the components are biodegradable.

Medical implants are another area. Most need hard components, such as joint replacements, but these tend to provoke inflammation in the human body. Tian explained that a major reason is that there's a mechanical mismatch between the hard titanium or steel and the soft tissues of the body; synthetic tissue could serve as an intermediary that eases the symptoms. "We also desperately need a synthetic organ that can filter selectively, like human kidneys do, and this may offer an avenue to that kind of biofiltration," Tian said.

Tian and Fang can also imagine the concept useful in soft robotics, an emerging field that allows robots to have abilities that hard materials don't—like squeezing into small places or delicately grasping objects.

"There are so many possibilities," Fang said. "We're really looking forward to exploring in more detail."

"This is really a new angle on biomimetics," Tian said. "Usually in this field we are mimicking natural evolution. But you can also emulate human practices that evolved—in this case, over a thousand years of making noodles in China."

More information: Yin Fang et al. Dynamic and Programmable Cellular-Scale Granules Enable Tissue-like Materials, *Matter* (2020). DOI: 10.1016/j.matt.2020.01.008

Provided by University of Chicago