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Nature Makes Wood. Could a Lab Make It Better?

For millennia, humans have been chopping down trees and harvesting plants. Lab-grown plant material might change that.

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FOR ALL THE ways that humans have toyed with nature, how we grow and extract materials from the forest and fields remains fundamentally unchanged. To get lumber, for example, we plant a tree, let it grow, and chop it down. Wood and other plant-based materials may be renewable resources, but obtaining usable forms typically requires lots of transportation, milling, and processing.

Now, a group of MIT researchers hopes to drastically trim these inefficiencies. The researchers grew wood-like plant tissue in the lab, which, if scaled up, could perhaps one day lead to the development of lab-grown wood, fiber, and other biomaterials aimed at reducing the environmental footprint of forestry and agriculture. Their work is described in a recent *Journal of Cleaner Production paper.*

“The hope is that, if this becomes a developed process for producing plant materials, you could alleviate some of [the] pressures on our agricultural lands. And with those reduced pressures, hopefully we can allow more spaces to remain wild and more forests to remain in place,” says Ashley Beckwith, the study’s lead author and a mechanical engineering PhD candidate at MIT.

Beckwith’s earlier research examined using 3D-printed microfluidics for biomedical applications like analyzing tumor fragments. But after she spent time working on and learning about organic farms, she became interested in more efficiently using agricultural and natural resources.

Lab-grown plant material wouldn’t depend on climate, pesticides, or arable land for cultivation. And producing only the useful portions of plants would eliminate discarded bark, leaves, and other excess matter, the researchers note. “The higher-level idea is about producing goods where it’s needed, when it’s needed,” says Luis Fernando Velásquez-García, a study coauthor and principal research scientist at MIT’s Microsystems Technology Laboratories. “Right now, we have this model where we produce goods in very few locations, and then we spread them.”

Growing plant tissues in the lab starts with cells, not seeds. The researchers extracted live cells from the leaves of young *Zinnia elegans*, a species chosen because it grows quickly and has been well studied in regard to cell differentiation, the process by which cells change from one type to another.

Placed in a nutrient broth culture, the cells reproduced before being transferred to a gel for further development. "The cells are suspended within this gel scaffold, and, over time, they grow and develop to fill out the scaffold volume and also transform into the cell types we're interested in," Beckwith says. This scaffold contains nutrients and hormones to sustain cell growth, meaning the plant-based material develops passively—no sunlight or soil necessary.

Yet a concoction of plant cells and gel won't turn into anything very useful without some tinkering. So the researchers tested how manipulating the gel medium's hormone concentrations, pH, and initial cell density, among other variables, influenced development and could affect the properties of the resulting plant tissues. "The plant cells have the capability to become different cells if you give them the cues for that," says Velásquez-García. "You can persuade the cells to do one or another thing, and then they get the properties that you want."

To achieve a wood-like material, the researchers had to prompt the plant cells to differentiate into vascular cell types, which transport water and minerals and make up woody tissue. As the cells developed, they formed a thickened secondary cell wall reinforced with lignin—a polymer lending firmness—becoming more rigid. Using fluorescence microscopy to analyze the cultures, the researchers could observe which cells were becoming lignified (or turning into wood) and also evaluate their enlargement and elongation.

Once it was time to print them, heating and then 3D bioprinting the gel allowed the resulting material to take almost any shape after it cooled and solidified. The dark green tissue that the research team produced is pretty firm, but it wouldn't be structurally strong enough for most construction purposes. For now, the thin, rectangular printed structures are only several centimeters long and are undergoing mechanical testing and characterization, Beckwith says, although printing larger versions is feasible. (Oh, and the researchers couldn't resist some fun, printing dog bone- and tree-shaped structures, too.)

T e *Zinnia elegans* project was more of a proof of concept for the growth techniques they tried; the next step could be translating them to other plant species that might produce more robust materials with useful traits. Initially, these materials could be more expensive than traditional plant products, Beckwith says, but being able to sidestep harvest, processing, and fabrication steps could reduce costs in the end.

T e researchers envision that it might be possible to someday print fully formed items, like furniture, but even just turning out ready-made blocks or beams of wood-like material could reduce the energy required to cut down and shape timber into usable forms. Water usage for preparing the gel media could be tightly controlled, reducing runoff. Growing plant tissues in the lab can take a couple of months, Beckwith says, yet that's much faster than, say, waiting 20 years for growing poplars to attain a profitable volume of timber.

In addition to the tantalizing possibilities of growing whole furniture, the plant-based materials could enhance fuels and chemicals production, says Xuejun Pan, a professor in the Department of Biological Systems Engineering at the University of Wisconsin, Madison, who wasn't involved in the study. "You don't have to necessarily grow a strong piece of wood. If you can produce a biomass, for example, as a future feedstock for bioindustry—competitively and productively—that could be attractive," he says.

This early work with printable organics might even provide insights into one day creating advanced materials and devices that use living cells to attain temperature-response or self-healing capabilities, says Jeffrey Borenstein, a study coauthor and group leader at the Charles Stark Draper Laboratory, a not-for-profit engineering research and development company that funded this project and is providing a fellowship to Beckwith. In plants, living cells can sense stimuli and respond to changes in their environment, a potentially transformative ability if it could be integrated into materials. "A material that can either grow or respond to the environment or heal itself would have great power," Borenstein says. "The fact that they're built out of living cells makes this possible in ways that would have been extremely complicated before."

Bioprinting plant cells hasn't been widely explored, the researchers say, and the work of selectively growing tunable plant tissues in printed structures is likely a first. Even the greenest ambitions have to be critically assessed, however. While anything that keeps trees in the ground sounds like a win, it's hard to predict the future implications of a lab-grown wood industry. For comparison, take cultured meat, which aspires to curtail the environmental costs of meat production, especially beef. Lab-grown meat is much farther along than lab-grown plant materials, but evaluating emissions reductions before an industry scales up can get murky. For example, swapping methane emissions from cattle for the carbon dioxide emissions from the electricity needed to run meat culturing facilities is an uncertain tradeoff. It's also not clear yet how much water an industrial process might use, compared to what's needed for ranching cattle.

Scaling up production of standardized lab-grown plant materials would also require a deeper understanding of the factors affecting cell development, from hormone levels and pH, to mechanical forces within the gel scaffold, to cell-to-cell biochemical signaling—in short, there's plenty more to study. And translating the *Zinnia elegans* growth techniques to other species could be challenging, says Velásquez-García, given other plants' varied composition. "Fully exploring the idea requires, perhaps, a lot more people with a lot more expertise," he says. But creating more sustainable solutions takes bold ideas, he believes, and sometimes lab-grown beats nature-made.

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