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10.11.17 | WORLD CHANGING IDEAS

## How Modern Meadow Is Fabricating The Animal-Free Leather Of The Future

The New Jersey startup is biofabricating a leather substitute that’s eerily like the real thing—without the environmental footprint.

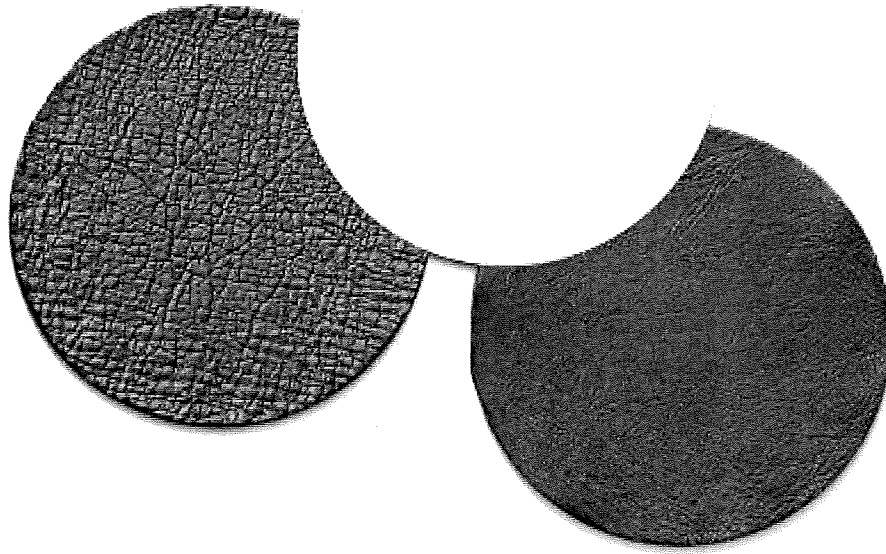


**BY EILLIE ANZILOTTI**

10 MINUTE READ

In a 72,900-square-foot former pharmaceutical facility in Nutley, New Jersey, test tubes sit atop lab tables crowded with microscopes and trays of materials. Out in the main area, huge fermentation vats churn.

This is not what you would imagine when you think of a leather production facility. Leather is one of the oldest materials in the world, created by killing an animal, stripping its skin of hair and fat, and treating the leftover materials with oils and chemicals (or way back in the day, urine and lime). Ancient Egyptians made leather sandals; cowboys rode on leather saddles. If any material seems outside the reach of innovation, it’s leather.



"It's a brand-new technology that enables us to grow the building blocks of nature, using a cell that we design and engineer ourselves." [Photo: courtesy Modern Meadow]

But Modern Meadow, a startup founded in 2011, thinks otherwise. Those test tubes and vats in the facility in Nutley are integral to its process of growing what it's calling the world's first biofabricated leather, made not from animals, but from lab-grown collagen that's assembled into flexible, adaptable forms of a new, leather-esque material that has the same properties as animal skins, but much less of the footprint.

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## It Looks, Smells, And Feels Like Real Leather--But It's G...

Modern Meadow is trying to revolutionize the multi-billion dollar leather industry.

Modern Meadow's sustainable alternative to leather is the latest innovation in the field of cellular agriculture, the process being used by companies like Impossible Foods and New Wave Foods, which are applying food science and genetic engineering to develop eerily accurate plant-based meats. The startup is revealing its product for the first time at an exhibit focusing on the future of fashion at the Museum of Modern Art in New York this fall. The company has designed a T-shirt created with its liquid biofabricated leather, called Zoa, to showcase the materials' properties and various uses.

"It's the changeability of the biofabrication process that allows us to explore a whole realm of possibilities." [Photo: courtesy Modern Meadow]

Gabor and Andras Forgacs, a father-son duo who also founded the 3D human-tissue-printing company Organovo, are the masterminds behind Modern Meadow. While Andras was living in China in the early 2000s, he fielded a lot of interest in his work at Organovo, which was, and still is, primarily applied in the medical field—developing and printing very small quantities of tissue to be used in reconstructive surgery, for example—but he also started to hear the same question: Would it be possible to apply his 3D printing technology for consumer products?

That, says Susan Schofer, Modern Meadow's VP of business development, got him thinking about skin cells, and leather in particular. Modern Meadow's first forays into leather substitutes involved growing the material from actual cow skin cells—a process not unlike that used by the Netherlands-based company Mosa Meat, which is developing “cultured meat” products in a lab using animal stem cells. Indeed, in the early days of Modern Meadow, the team was looking to develop meat alternatives as well, but decided to zero in on biofabricated leather, as the concept was, compared to meat alternatives, relatively unexplored.

And there is a huge need to do so: Despite its long history of use as a clothing material, leather sits at the intersection of some of the most wasteful and polluting activities on the planet. It's derived from livestock—mostly cows, pigs, goats, and sheep—the mass raising for which meat and materials production accounts for more than half of global greenhouse gas emissions. And while leather has uses beyond fashion and accessories, it's a staple in that industry, which comes second only to oil as the world's most polluting sector.

By bypassing the large-scale livestock industry entirely, Modern Meadow presents an alternative that's sustainable at both ends of the supply chain. [Photo: courtesy Modern Meadow]

Current substitutes, like pleather, aren't any better. Because they're made from oil in the form of plastic—usually PVC or polyurethane—they're dependent on fossil fuels and not recyclable. Modern Meadow, on the other hand, is naturally derived. It's naturally derived, unlike other leather substitutes. And unlike genuine leather, it leaves no environmental footprint on the sourcing side. By bypassing the large-scale livestock industry entirely, Modern Meadow presents an alternative that's sustainable at both ends of the supply chain.

Getting to this point, though, was a process of trial and error. Modern Meadow's initial process of growing leather from animal cells is called tissue engineering, says Suzanne Lee, the chief creative officer, and it involves raising the cells in a material composed, in part, of a serum extracted from unborn calves. The process is very particular and precarious—if bacteria infiltrate the cell growth process, the whole operation could derail, and the equipment needed to protect against that event is very expensive. Furthermore, there's no real supply chain in place to source either the animal cells or the serum needed to grow them in, so acquiring them at scale would be prohibitively expensive, Lee adds. And the fact that the material is, fundamentally, animal-derived negates the possibility of claiming the label “vegan” or “animal free.”

So in 2014, Modern Meadow switched its manufacturing process. Instead of using animal cells, the company began growing collagen—which is essentially what is left over after the hair, fat, and tissues are removed from skin—from yeast. “It's a brand-new technology that enables us to grow the building blocks of nature, using a cell that we design and engineer ourselves,” Lee says. “In this instance, that cell is collagen, the protein that you find in your skin and in animal skin, and that really is the fundamental material that composes leather.”

"No one has ever engineered a yeast cell to produce collagen in the quantity that we need it to." [Photo: courtesy Modern Meadow]

But of course yeast does not, in and of itself, produce a collagen that perfectly mimics the collagen found in animal skin. Through a process of DNA editing, Modern Meadow adds two other enzymes (which they won't name) to the yeast culture (which is rather beer-like in color) to enable it to produce collagen that effectively replicates skin protein. Those collagen strains ferment, they coalesce into a malleable network of fibers.



The process, Schofer adds, is highly scalable. “No one has ever engineered a yeast cell to produce collagen in the quantity that we need it to,” Lee says. That ability has allowed Modern Meadow to drive down its production costs to the point where their materials are on par with the cost of traditional leather. The yeast is fermented in large vats, like those used to make beer and wine, and the resulting liquid collagen is both large in quantity, and highly adaptable to various uses.

The Modern Meadow team is able to create not just a uniform sheet of leather (though it can certainly do that), but a whole variety of materials. [Photo: courtesy Modern Meadow]

That, Lee says, is where Modern Meadow's innovative properties really become apparent. "Once we've purified the collagen and created this liquid leather, we have a whole toolbox that's open to us," Lee says. "We can mold it or shape it into any form we like." In other words, Modern Meadow is creating a material that is leather-like in its fundamental physical properties. But what makes it really resemble different forms of leather is how it is treated after it's produced.

Because Modern Meadow's product and animal-derived leather have, essentially, the same chemical structure, they react in much the same way to external forces. Like animal leather, Modern Meadow's product is also biodegradable, but can be tanned and treated for more durability, Lee says. That tanning process, too, is what gives animal leather its distinctive smell, so Modern Meadow duplicates that, as well. Though the MoMA shirt is just black leather, the biofabricated material can be also be dyed.

The Modern Meadow team is able to create not just a uniform sheet of leather (though it can certainly do that), but a whole variety of materials. There's a paper-thin leather that can be poured onto fabric as a T-shirt applique; there's a thick, pebbled hide that could form a handbag. Zoa, the liquid leather modeled in the T-shirt at the MoMA, can act almost like paint—the material can be drizzled into almost Jackson Pollock-like patterns. It can also act as an adhesive. The MoMA shirt is a patchwork of mesh and cotton, joined together by the liquid leather, which merges seamlessly with the other materials.

The startup is revealing its product for the first time at an exhibit focusing on the future of fashion at the Museum of Modern Art in New York. [Photo: courtesy Modern Meadow]

While Modern Meadow doesn't speak to how, exactly, they are able to manipulate the liquid collagen to form this range of leather substitutes ("that's the secret sauce," Lee says), "it's the changeability of the biofabrication process that allows us to explore a whole realm of possibilities," Lee adds. The fibers that result from the yeast fermentation process can be molded in a variety of ways, she says. They can be pressed into tough, thick slabs or thin

sheets, or they can be kept viscous and used like a paint or a glue, as seen in the shirts Modern Meadow has created.

The possibilities of the new material has the design and fashion world very excited. Modern Meadow has been approached by around 150 companies from a variety of sectors: fashion, sport, automotive, and interiors. The company won't disclose the names of their partners, but it says that around two will be bringing products developed with Modern Meadow to market next year.

While interest in Modern Meadow has been strong, the process of explaining to companies and designers how, exactly, the material works has been a bit of a challenge, Schofer says. "Fashion, and any sector that uses textiles or traditional leather, are not really used to the timelines of biotech R&D," Schofer says. Modern Meadow explains to companies that what they're offering them is not a raw material, but an opportunity to work together to develop a product that will integrate specifically with a design. So for example, if a brand wants to develop a T-shirt with biofabricated leather decals, Modern Meadow will not just present them with a sheet of leather that they can then cut up and applique; instead, they'll work with the designer to mold the leather to the design, adjusting the flexibility and weight accordingly, and the material will adhere seamlessly to the fabric.

Fashion designers will have to communicate effectively with Modern Meadow and tell the company exactly what they want out of the material, and how much they need. [Photo: courtesy Modern Meadow]

That malleability, Lee says, will help companies do away with the waste generated by offcut fabric scraps, and think more intentionally about their designs. However, doing so will necessitate that designers rethink both their process and the scope of their collaboration with materials providers. They will have to communicate effectively with Modern Meadow and tell the company exactly what they want out of the material, and how much they need.

Schofer and Lee believe that the advantages of working with Modern Meadow will outweigh the potential difficulties. Using Modern Meadow's materials will not necessarily be more expensive—sourcing animal products is very expensive. And especially for luxury designers, who are in the business of trying to push the boundaries of innovation in the industry, working with Modern Meadow to develop unique applications of leather—in all its different, biofabricated forms—holds a lot of appeal, as does the material's light environmental footprint. But still, questions remain: As Modern Meadow grows, will it be able to remain committed to tailoring its leather for exact uses? Or will it have to default to mass-producing in order to meet demand? And if so, will it be able to ensure that its material does not go to waste?

These questions, though, are still far in the distance; Modern Meadow has a ways to go before it hits the mass market. Still, though, the company is gearing up for massive growth—it's already expanded from around 10 people in 12,000 square feet of lab space when Schofer started, to around 70 people in a 72,900-square-foot space, and backing from the likes of Horizons Ventures and Tony Fadell.

"We're really focused on the long-term," Schofer says. Just like how Modern Meadow's collaboration with designers and other industries is not a one-and-done exchange, but rather a long, collaborative process, so the company will continue to iterate its product. "It'll be multigenerational work to constantly improve the strain of the yeast and work on creating an organism that will produce as much collagen as we can get it to," Lee says. "That's ongoing, and it'll probably be ongoing for the life of the company."

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#### ABOUT THE AUTHOR

Eillie Anzilotti is an assistant editor for Fast Company's Ideas section, covering sustainability, social good, and alternative economies. Previously, she wrote for CityLab. More

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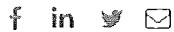


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TECH

## This leather is made in a lab, not from livestock



Lora Kolodny | @lorakolodny

Published 7:00 AM ET Fri, 9 March 2018 | Updated 12:04 PM ET Fri, 9 March 2018

- European chemicals giant Evonik is partnering with Modern Meadow, a start-up that brews leather rather than making it from livestock.
- Modern Meadow is backed by Li Ka-Shing's Horizons Ventures, and Breakout Ventures, a Peter Thiel fund, among others.
- The synthetic biology start-up is poised to disrupt the \$100 billion leather industry.



Modern Meadow figured out a way to make real leather  
in a lab without hurting any cows

7:14 AM ET Fri, 9 March 2018 | 00:50

A start-up called Modern Meadow has developed a way to brew leather in a lab, without harming any animals.

Here's how it works, according to Modern Meadow CEO and founder, Andras Forgacs:

"We have engineered a strain of yeast — like a cousin of what you'd use to brew beer — which can produce collagen through fermentation. Collagen, which is found in animal skins, is the main biological building block of leather. We assemble it into a range of materials that become our 'Zoa bioleather.'"

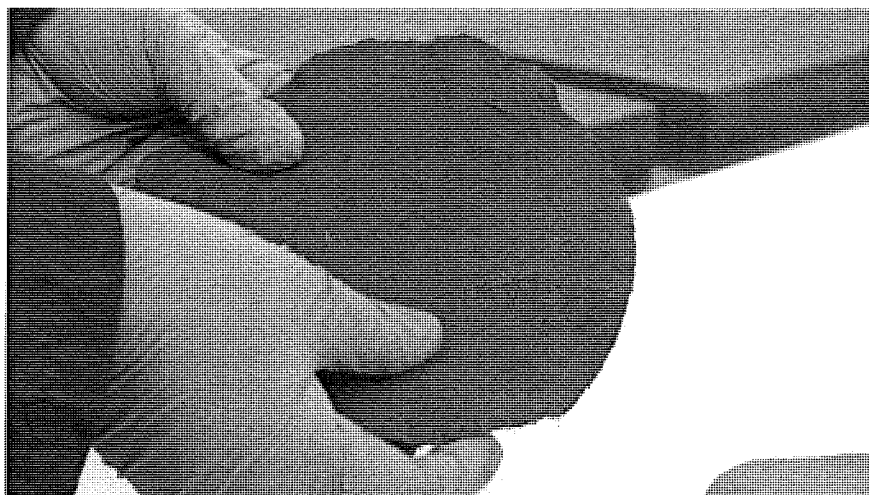
In recent months, Modern Meadow has refined its technology, so that its leathers can be brewed on the equipment found in large commercial fermentation facilities that make food and medical-grade products for the masses.

Chief Technology Officer Dave Williamson told CNBC that Modern Meadow has also struck a joint development partnership with European chemicals giant Evonik that will help it scale production, and make Zoa bioleathers available to designers of luxury goods.

The company isn't yet disclosing the names of designers who have access to its leathers, which feel and even smell like leather made from animal skins. However,

Forgacs said Modern Meadow has been fielding inquiries from hundreds of designers across fashion, sports, automotive and other industries.

Funded by Li Ka-shing's Horizons Ventures, Iconiq Capital, Breakout Ventures (a Peter Thiel affiliated fund) and Temasek, among others, Modern Meadow is poised to disrupt the \$100 billion leather industry.

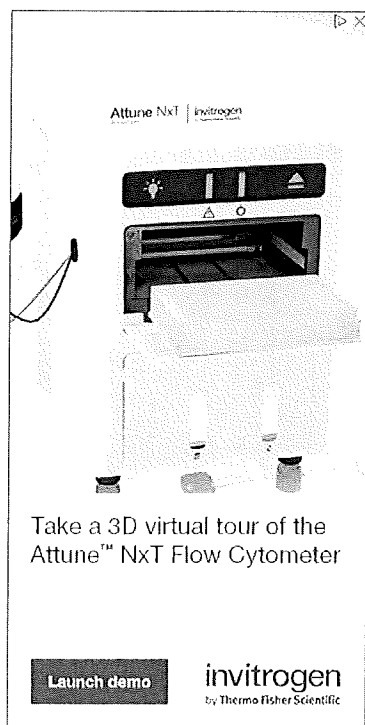


Source: Modern Meadow

The company's bioleathers take just two weeks to create in a foundry or a lab, which is far shorter than the amount of time it takes to raise livestock and put animal hides through a chemically intense process. They can be made to match any thickness, texture or color a designer specifies.

Biofabricated Zoa leather can be delivered in sheets, like traditional leather. But it can also be poured into place, serving as a seam in a given product. "It can go anywhere traditional leather would go, and beyond," Forgacs said.

Even the Museum of Modern Art (MoMA) in New York has taken notice of Modern Meadow's futuristic leather. It asked the start-up to create a graphic t-shirt for an exhibition last year called "Items: Is Fashion Modern?" After the show, MoMA acquired the shirt into its permanent collection.



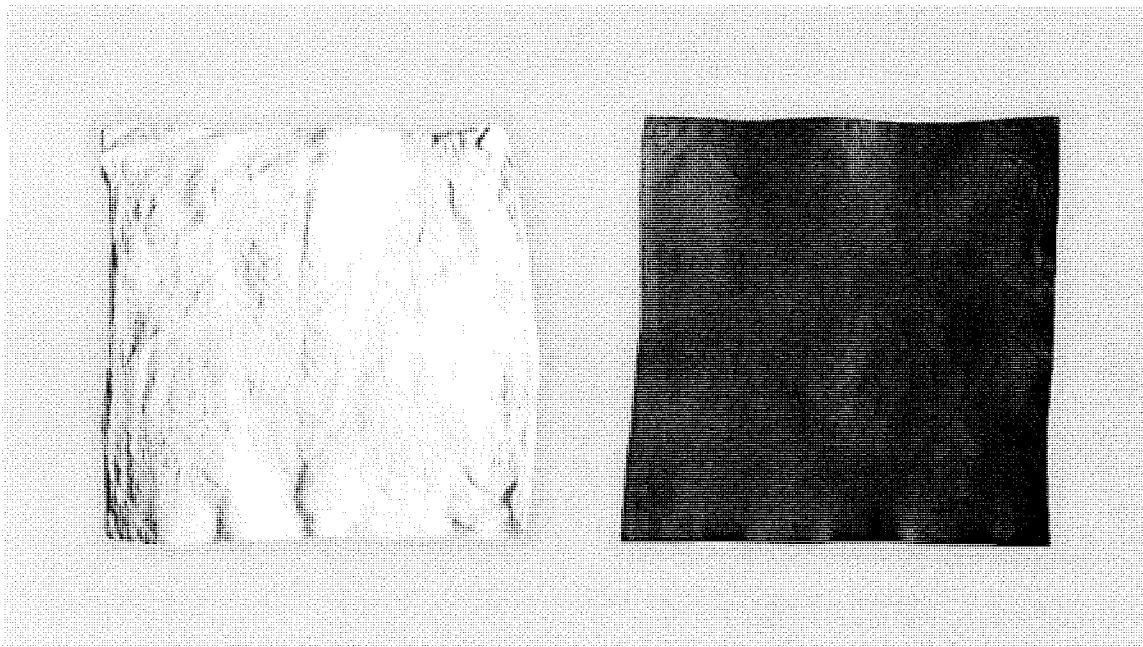
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## SCIENCE

# Leather, Grown in a Lab Without Cows

Modern Meadow's factory will crank out leather via yeast fermentation.

SARAH ZHANG SEP 21, 2017



A rawhide made from collagen grown in yeast (left) and semifinished, dyed hide (right)  
(MODERN MEADOW)

To make leather, first you have to raise a cow.

Or another animal, though you really do need the whole animal because since pretty much the beginning of time, it has not been possible to grow skin for leather without the attendant flesh and bone and blood and guts.

But now a company called Modern Meadow says it can “biofabricate” leather without the rest of the cow. It does not quite grow cow skin, either; it grows a strain of yeast engineered to produce collagen, the protein in skin that gives leather its strength and stretch. Traditionally, making leather amounts to removing almost everything from skin (fat, hair, etc.) that *isn't* collagen. Modern Meadow is basically skipping ahead. Once purified, pressed into sheets, and tanned, their vat-grown collagen becomes, essentially, leather.

No dead cows. No scars or nicks. And none of the petrochemicals used to make pleather or vegan leather.

It's a radical new way of making leather, reliant on genetic engineering and decoupled from the processes of traditional agriculture. Engineered yeasts have long been used in the production of drugs like insulin, but recently—and perhaps surprisingly given the debate over genetic engineering—they're entering the world of luxury goods: spider silk, perfume, and now leather.

When Modern Meadow publicly unveils its leather in the next month—in the form of a “reimagined” graphic T-shirt—it will not be at a store but at a fashion exhibit at New York's Museum of Modern Art. The company employs a chief creative officer as well as a professional tanner, and it's been carefully cultivating its mystique. Modern Meadow doesn't just want to imitate leather, the company keeps reiterating; it wants to reimagine leather, transcending the physical limits of a cow.

The T-shirt “will change the way you think about leather,” promised David Williamson, the company’s chief technology officer, though he could not yet reveal to me how.

\* \* \*

Modern Meadow was not always so interested in fashion. Its founders—CEO Andras Forgacs and his father and chief scientific officer Gabor Forgacs—had previously started the company Organovo to grow human tissue for medical and pharmaceutical research. Going from engineering human tissue to animal tissue, says Andras Forgacs, seemed like a logical next step. In 2011, they started Modern Meadow with the goal of growing leather and eventually meat in tissue culture.

But they quickly ran into a problem of economics. Organovo only had to make tiny quantities of tissue for medical purposes, which it could then sell at high prices. “The value of that is super high when you’re dealing with life and death,” says Forgacs. A steak requires growing many thousands of times more cow tissue, at a much lower price per ounce. The economics of leather are slightly better.

Forgacs tells me now that he had always planned to focus on leather first. But the idea of the lab-grown meat fits into an established narrative of what biotechnology is for, and meat’s ethical and environmental problems are more ubiquitous than leather’s. The meat angle got quite a bit of early press attention. As late as 2015, Modern Meadow was giving journalists a taste of cultured “steak chips.” Today, its website no longer has any mention of cultured meat.

A sheet of collagen produced by Modern Meadow (Modern Meadow)

Modern Meadow initially tried to grow cow skin cells for leather much like how it grew cow muscle cells for meat. Mammalian cells are finicky, however, and they require specific and nutrient-rich medium. The problems were twofold: One, the medium required to grow the cells includes serum extracted from unborn calves, thus negating any animal-free promises; and two, all kinds of unwanted

bacteria and yeast will grow in a nutrient-rich medium, requiring expensive equipment to maintain sterility.

Williamson walked into these problems when he joined Modern Meadow from DuPont in 2015, and he eventually decided the mammalian cells had to go. Modern Meadow was going to get into hardy, fast-growing yeast. “Yeasts are the things you worry about contaminating your mammalian tissues,” says Williamson. And since yeast is already widely used to manufacture molecules of interest—alcohol for beer and wine, for example—there is plenty of ready-made industrial-scale equipment tailored to yeast fermentation.

The challenge, then, is getting yeast to make bovine collagen. It’s easy enough to splice genes from another species into the microscopic creatures. Scientists have been doing this for decades, and it’s how pharmaceutical companies use vats of yeast to make human insulin. But yeasts do not spit out collagen that automatically assembles into sheets of leather. Williamson’s team had to add two other genes for enzymes that help modify the collagen’s molecular structure, and then—using another process he declined to detail—Modern Meadow forms it into sheets of rawhide. The rawhide can be tanned just like the stuff that comes from cows.

Williamson calls traditional leather making a top-down process. You start with a cow skin, strip off the fat and hair, cut out imperfections, and work around parts of the skin that are thinner or weaker than others. At Modern Meadow, he says, “we’re doing bottom-up assembly.” By tweaking the collagen network, the team can make leather whose size is unlimited by the physical size of



cattle, or more tear resistant, or impossibly thin. It could even tinker with the molecular structure of collagen—optimizing it for one property or another.

As part of its entry into the world of fashion, Modern Meadow is quick to tout its design credentials. Williamson notes that his scientists work hand in hand with the company's designers, led by chief creative officer Suzanne Lee, who has experimented with making clothing from kombucha. Forgacs says the company is also partnering with several brands, though he could not yet name them.

The leather industry is watching too, curiously but with reservations. Steven Lange, director of the Leather Research Laboratory at the University of Cincinnati, told me to keep the bigger picture in mind: “You don't want to lose sight of the fact we're dealing with a waste byproduct of the food industry.” In other words, it's demand for meat and milk that drives the supply of leather.

Modern Meadow was in fact onto something with its initial if overambitious twin goals of meat *and* leather. (Other companies like Memphis Meats have since taken up the challenge of culturing muscle cells in a lab.) The production of the meat and leather have been connected for millennia for good reason. Collagen-making yeasts allow Modern Meadow to build a new leather supply chain from scratch, but it still must exist in a world where animal agriculture has created vast, entangled supply chains.

It may now be possible to make leather without a cow. The problem that remains is people still want the rest of the cow





