A house made from mushrooms and a ski jacket from microbes? Synthetic biology is poised to revolutionize what we can do with crops

Imagine if we could redesign nature by making a house out of mushrooms, a ski jacket from fermented microbes, and seafood made in a lab. What if we could combat cancer using targeted genes from broccoli? You won't have to imagine for long, as scientists are finding new ways of recreating the materials and foods we depend on every day using a combination of fermentation and synthetic biology.

I just got out of the lake this morning after a long swim. It was lovely…blue skies, a bit of early morning breeze, and a loon calling nearby. Afterward, I am always starving, so I dutifully made my post-workout smoothie. As I blended my easy and quick protein powder mixed with milk, hemp hearts, yogurt, avocado, and fruit, I started to think of the new technology on the block – Synthetic Biology.

Moving beyond the lab…

What if my milk and yogurt didn't come from a cow, an almond, or an oat, but really from fermented yeast? What if the steak I planned to cook for dinner was made from mushroom roots? The same food we know and love, but just made a different way. But make no mistake about the term 'synthetic'.

The word 'synthetic' can make people fear companies are making 'fake' food…but that is not what is happening at all. It is really taking food proteins and putting them through the fermentation process. Similar to Kombucha, or the beer we drink on the weekend, fermentation technology has been around for thousands of years. Today, we have just adapted fermentation to the 21st century. Though there are about four different methods of synthetic biology, for the purposes of food, we are mainly talking about the fermentation process.

So how can these innovations be used in food and agriculture to feed the growing population sustainably and nutritionally? Synthetic biology seems to have some of the answers. So much so, that by 2030, it is predicted that most people will have eaten, worn, or used something created by synthetic biology. McKinsey predicts that the annual direct economic potential ranges between $2-4 billion, with around $1 billion of that attributed to material changes in agriculture, aquaculture, and food. Markets and Markets has an even higher prediction; that by 2026, the market will reach $31 billion.

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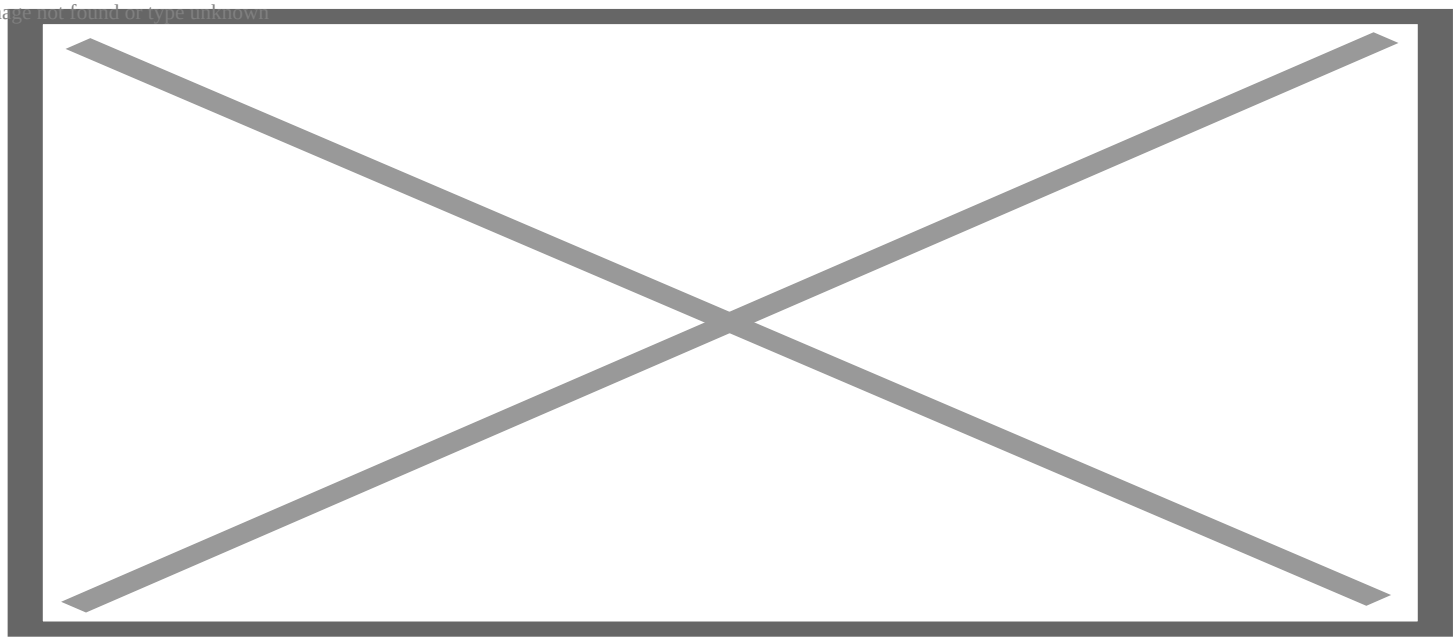

The SynBioBeta report ranks the food and food ingredients industry as the second-highest in the number of investments, behind therapeutics and before life sciences, agriculture, and energy.

Solutions in agriculture range from fully utilizing the soil microbiome to aid in sustainable and increased agricultural production.

And solutions in food are replacing traditional meat, poultry, and seafood with meat created in a lab either by growing cells in a petri dish or fermenting bacteria or yeast.

Some of the companies that create these unique products state they are more sustainable for the environment and can address animal welfare issues.

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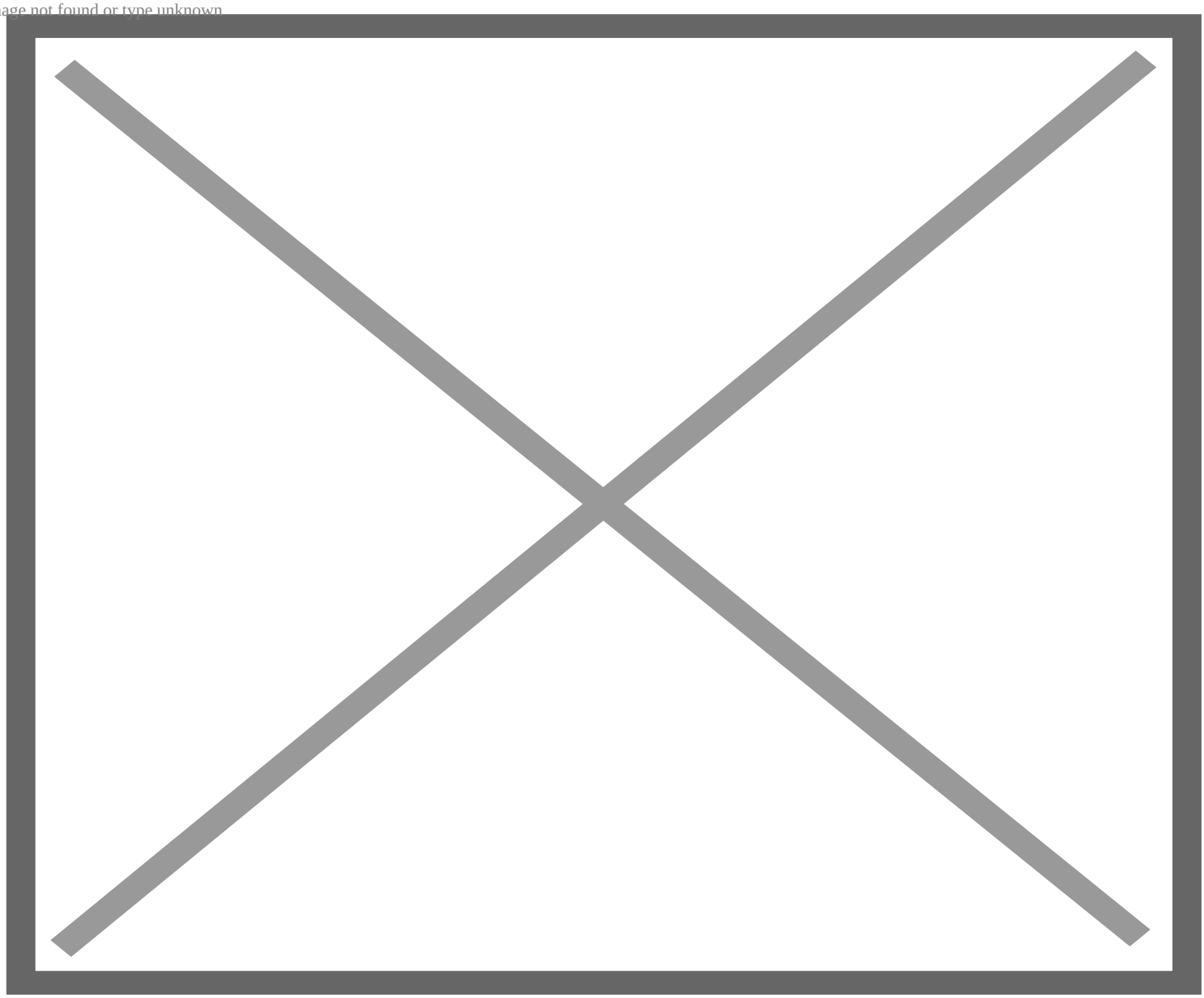

…And into your fridge

If any of you have eaten the Impossible Burger, then you have experienced food made with synthetic biology. Remember when you took a bite and it was red and juicy, just like a hamburger? This was accomplished by isolating the leghemoglobin protein in the soybean plant that carries oxygen to the root nodules via the protein heme.

In animals, hemoglobin is essential and carries oxygen from the lungs to the cells. That is the part of the hamburger from a cow that ‘bleeds’. Scientists at Impossible Foods make the heme with the leghemoglobin and fermenting it with genetically engineered yeast.

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Let’s say you want to make ice cream or cream cheese, but not use milk from a cow. A company called Perfect Day teamed up with agricultural company ADM to create milk proteins without the milk.

Perfect Day orders the necessary milk proteins, whey, and casein from a company with a genetic database that can send you actual genes in the mail. Scientists at Perfect Day combine these proteins in a fermentation tank with a specific synthetically-engineered microflora that ‘supercharges’ the proteins. Then the substance we think of ‘milk’ is created. They even have a non-fat ‘fat’ called Epogee to make the ice cream taste delicious without the calories.

Who would have thought fermenting fungi could create an edible protein? The company Enough also uses fermentation technology to create a meat-like substance, called ABUNDA, by fermenting fungi with sugar feedstocks from grains. This fermented meat substitute has fiber, all nine essential amino acids, vitamin B12, zinc, and iron.

Partnering with Unilever, Enough’s website states that producing one million tonnes of ABUNDA will replace five million cows, over 1.2 billion chickens and reduce more than five million tonnes of CO2.

Broadening synthetic applications

Of course, cows produce much more than just meat that we eat. At least 47% of the cow is used for leather, garden fertilizer, jet engine lubricants, tallow…the list is endless. Much of these synthetic materials replace the traditional cow hide, alligator skin, or spider silk. In one case, even jet engine lubricants.

The leather coat you wear, or the belt, even the shoes, all come from an animal – most likely cattle. Modern Meadow, however, is replacing animal-based leather with biofabrication using bio-engineered proteins and fermentation. They grow their protein cells with a yeast culture into collagen which, in turn, goes into making various materials (check out their very interesting process here).

A backpack out of mushrooms? Ecovative Design grows material using the familiar button mushrooms. By fermenting the mycelium – the root structure of the mushroom – they can turn proteins such as cellulose, lignin, collagen, or non-spider silk into strong, soft silk, leather, or even whole-cut meats.

The interesting phrase here is ‘whole-cut meats’. Normally, cell-based meats (those made in a lab) or plant-based meats lack the ‘scaffolding’ to hold it all together. That is why most of the alternative meats are made into a ‘hamburger’. But these fermented mushrooms from Evocative Design can grow into a structure that can help create a steak or a specific cut of meat.

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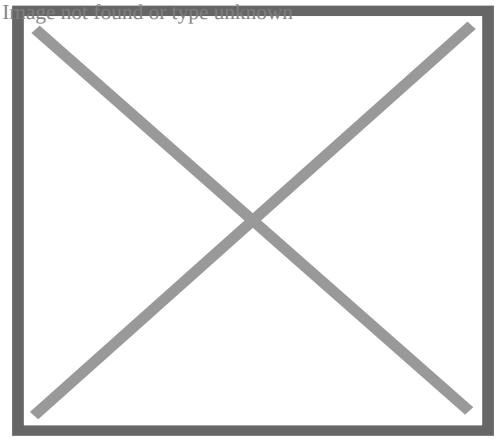


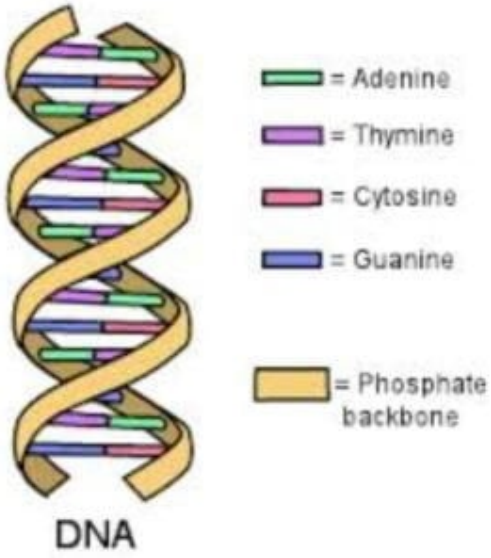
Working in conjunction with Bolt Threads, the British fashion designer Stella McCarthy created a ‘leather’ purse out of the mycelium. Bolt Threads has created manmade spider silk ‘stronger than steel and softer than a cloud.’

Synthetic biology can now supercharge your vegetables, too. For instance, we all know that broccoli is good for us. Today, that saying has never had more meaning. Scientists in Singapore used synthetic biology to restructure a common and benign form of E. coli, Nissle, that is found in our gut. They engineered the bacteria into a probiotic that attaches to the cell of a cancerous tumor in the colon. These bacteria then secreted an enzyme – found in broccoli – into the cell. This concoction became an anti-cancer agent killing up to 75% of tumors in mice. In the future, this could be used as colon cancer

prevention or a way to ‘mop up’ cancer cells after surgery, something just plain old broccoli can’t do.

Unfolding and reconstructing DNA

We have come a long way from Gregor Mendel when he began experimenting with crossbreeding pea plants in 1865.



DNA is the blueprint for every single organism. Synthetic biology can rearrange DNA to make whatever material or organism we want. This may sound confusing but let’s start with the basics.

We are familiar with computer coding using a combination of 0s and 1s. It always amazes me what you can do with just two numbers. Well, take four chemical building blocks identified primarily as their letters: A, C, T, G.

These chemical building blocks, called DNA, come together to form genes that instruct our cells to function how we want.

Our genes give us the color of our eyes, our height, and all the genetic codes that make us human. Remember Legos? You could build whatever was in your imagination: an airplane, a motorcycle, a spaceship, the list was endless. Think of the four letters in DNA as four different colored and shaped Lego pieces. Synthetic biology allows us to recreate the DNA in our food and other materials, essentially making our own Lego designs with whichever instructions we choose.





Mail-order genes?

What makes this easy – relatively – are companies that specialize in synthesizing and selling genes. They have what is called a genetic library. We used to go to a library to check out books. Now we look online to find the gene we want and get it delivered to our lab or office. Twist Biosciences "gives you the flexibility to get the DNA you want, the way you want it. Think bigger, expand your design scope, and accelerate discovery".

If someone is designing and building new products, Illumina provides the infrastructure to figure out the genetic pattern of the A, T, C, & Gs. Like the Legos, you need to make a structure so Illumina will tell you which genes you need.

A company like Ginkgo Bioworks will restructure the 'Legos', or genes, into what you want. But you can't make the Lego airplane without knowing which pieces you need.

A company doesn't need to have the technical skills to be a gene sequencer or a protein builder to make milk or meat – they only need certain starter feedstocks, usually sugars that come from grains. Then it goes through the fermentation process to make the desired proteins. For instance, if a company is an expert in fermentation, then they can order the genes they need from a company like Ginkgo Bioworks to make any kind of meat, milk, fabric, or building material.

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The world needs protein!

Synthetic biology can synthesize parts of DNA to make plants more resilient to disease, have greater nutrition, and be resistant to climate change.

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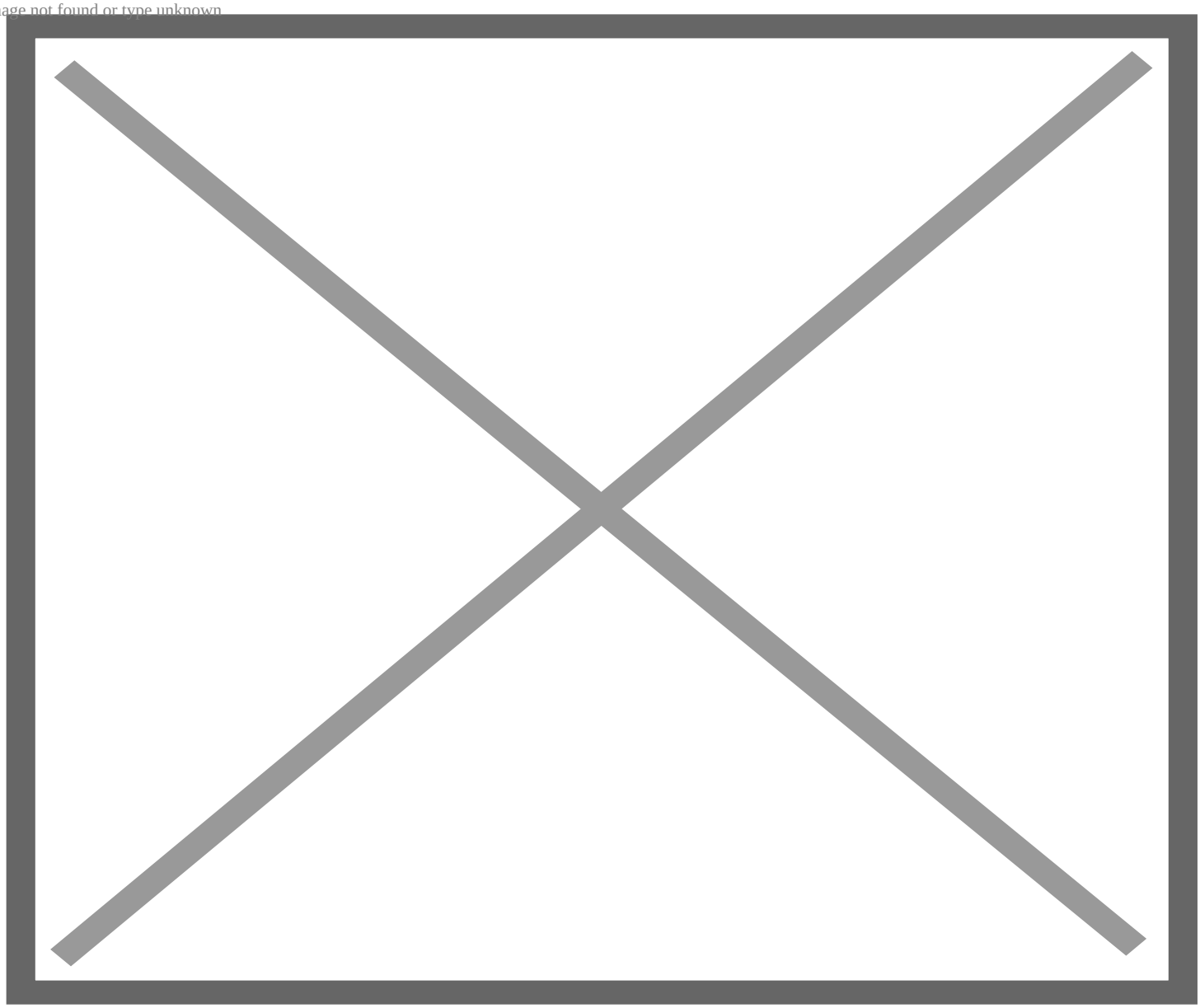

It shouldn’t come as a surprise that the most well-funded companies in the synthetic biology space are all focused on feeding people. A high-protein diet is more than a new eating craze — it’s essential to our health. Protein is essential not just after we run, jump, swim, or left weights. It is the basic building block of life that “keeps the lights on” in our bodies.

Our growing world needs to fuel itself with protein. As COVID-19 continues to rage, it’s more important than ever that humans produce and consume enough protein to boost their immune system, heal from illness and injury, and move and store nutrients throughout the blood.

That is probably why the amount of protein consumed by the world is such a staggering number. The

world eats about 467 million metric tons of protein a year. If you put all that meat in rail cars, how long is that train? It would go around the Earth's equator almost two times.

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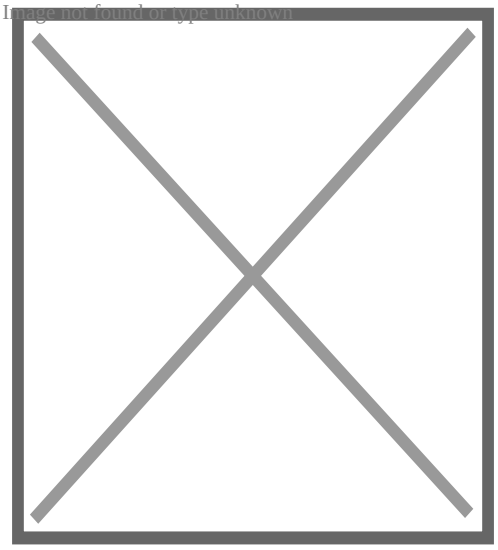

And by 2035, those 532 million metric tonnes of protein will go around over two times, which is essentially adding a train of railcars going from coast to coast 2.5 times across the United States. The world needs to grow a lot of protein!

Precision fermentation *won't replace all protein, but it will certainly help fill up the rail cars.* While we just focused on protein, the market has significantly more potential via the broader technology of synthetic biology.

There is a race between Europe, China, and the U.S. to have the most competitive technology and capture the most of the potential $31 billion in global revenue. That competition will spur excellence, innovation, and an expediated timeline.

This means sooner, rather than later, we may soon have our broccoli spears fighting cancer and grown in a lab down the road.

The bottom line

This new ability to use genetic building blocks to produce everyday items opens the door to rethinking our food, medicines, the clothes on our back, the roofs over our heads, and everything in between. Of course, this is not a fait accompli. There are many challenges: consumer acceptance, processing facilities, transportation, logistics, labor, and not to mention how this could affect the face of agriculture. But looking at how quickly investors are flocking to this space, the disrupting technology is here.

Lucy M. Stitzer is a food writer and regular contributor at Dirt to Dinner. She served on the Board at the food company Cargill for many years.

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