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MIXING OUR WAY TO A NEW KIND OF MEAT-LESS "MEAT"

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YOUNG REVIEWERS:

ATHARV

AGE: 12

Many people around the world love to eat meat, but producing it the traditional way uses a lot of land, water, and energy—and harms the environment. Scientists are looking for better ways to provide the protein people need in their diets, by exploring alternative protein sources like plants, fungi, insects, and animal cells grown in tanks. Each source has its own benefits and limitations when it comes to taste, nutrition, and cost. By mixing these various ingredients together, scientists can create hybrid food products that taste better, are more nutritious, and have a smaller impact on the planet. Hybrid food products still face challenges, like high costs, the need for safety checks, and getting people to try them. If these problems can be solved, hybrid food products could help feed a growing population in a more sustainable way—and change the future of food.

THE PROBLEM WITH PROTEIN

Have you ever tried a veggie burger, oat milk, or a plant-based chicken nugget? These and similar products are made to replace foods like meat, milk, and eggs. People choose plant-based foods over animal-based ones for all kinds of reasons, from health to the environment to animal welfare. Animal-based foods are usually rich in protein, which is an important nutrient that helps build muscles, repair the body, and generally keep people healthy. While protein is found in both animal- and plant-based foods, meat is still the most common protein source for much of the world.

Getting most of our protein from animals comes with a huge cost to the environment. Raising animals uses vast amounts of land, water, and energy, and it produces damaging pollution including greenhouse gases that contribute to climate change. Clearing forests to make room for grazing animals or to grow their food damages ecosystems and pushes wildlife out of their homes. Also, keeping lots of animals in crowded conditions can spread disease and lead to the overuse of antibiotics, which creates health problems for people, too [1]. As the human population grows and the amount of meat people eat keeps increasing, it will become even harder to feed everyone without harming the planet.

WHERE DO ALTERNATIVE PROTEINS COME FROM?

Is there a better way to get the protein we need—one that is healthier for people, animals, and the planet? Scientists have been investigating **alternative proteins** made from plants, fungi, insects, or even living animal cells grown in special tanks (Figure 1) [2]. Some of these alternative proteins are already in foods available in grocery stores, but others are still being developed.

ALTERNATIVE PROTEINS

Proteins that come from non-traditional sources like plants, fungi, insects, or cells grown in tanks instead of from farm animals.

PLANT PROTEINS

Proteins found in foods that come from plants, such as soybeans, peas, chickpeas, and oats.

MYCELIUM

Thread-like parts of fungi that normally grow underground but can also be grown in tanks to make meat-like foods.

Plants

Plants are the most familiar alternative protein option. Many plants—like soybeans, peas, chickpeas, and oats—naturally contain protein. **Plant proteins** can be turned into meat substitutes like veggie burgers, nuggets, or sausages. Some plant-based products taste pretty good and are easy to find in stores. But many do not quite match the flavor, texture, or nutrition of meat. Also, they are often made using lots of added ingredients and harsh processing operations, which some people worry might not be very healthy.

Fungi

When you think of fungi, you might picture mushrooms on a pizza or growing in the woods. But the mushroom you see is only the tip of the iceberg. Beneath the surface is a network of tiny thread-like structures called **mycelium**. These threads grow through soil or other materials and help the fungus absorb nutrients.

Figure 1

Alternative protein sources can be obtained from plants, insects, mycelia, microbes, and cultivated animal cells. Depending on the food product to be made, the alternative protein ingredients are processed either mechanically (e.g., by shaping, mixing, or pressing the ingredients in special machines to turn them into patties or nuggets) or they are grown in large tanks called bioreactors, under carefully controlled conditions. Hybrid meat products can be generated by combining different kinds of protein sources.

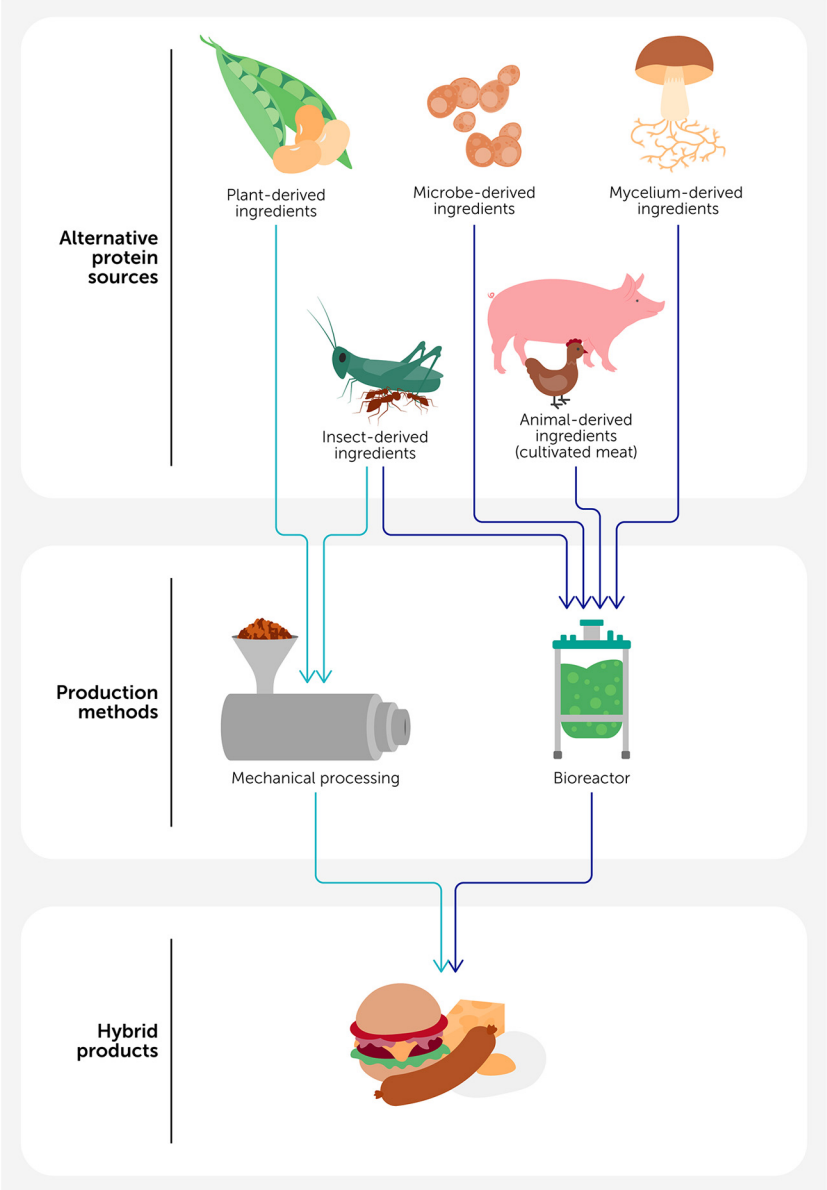

Figure 1

BIOREACTOR

A large tank where cells or microbes are grown under controlled conditions to make food ingredients or other useful products.

Scientists have been growing mycelium in large tanks called **bioreactors**. Inside a bioreactor, conditions like temperature and oxygen are carefully controlled to help the fungus grow quickly. The resulting mycelium can be shaped into meatless burgers, nuggets, or sausages. Mycelium is naturally fibrous and chewy, which makes these foods feel surprisingly similar to meat. Mycelium also contains protein, fiber, and important vitamins and minerals. One popular brand, Quorn™, already uses mycelium to make meat-free products you can buy in stores. Still, the taste of fungi is not quite the same as meat, so it is often mixed with other ingredients to improve the flavor.

Cultivated Meat

CULTIVATED MEAT

Meat grown from animal cells in a tank, without raising or slaughtering animals.

Cultivated meat is "real" meat—but produced without raising and slaughtering animals. Scientists can take a few cells from a chicken, cow, pig, or fish (using a biopsy or a small needle, without harming the animal) and grow them in a bioreactor, using the right combination of nutrients and carefully controlled growing conditions. Over time, the cells multiply and form animal tissue. Cultivated meat has many of the same kinds of proteins, fats, and nutrients as regular meat, so it can offer the same health benefits—and it even cooks and tastes a lot like meat, too. Right now, cultivated meat is still very expensive to produce and is not widely available. A few countries have approved it for sale, but in most places, it is still being tested and developed.

Microbes

PRECISION FERMENTATION

A process in which microbes are given instructions to make specific ingredients, like proteins or vitamins, in a tank with carefully controlled conditions.

Scientists are also working on using tiny microbes—like bacteria, yeast, and certain fungi—to produce alternative proteins. These microbes can be grown in bioreactors, just like fungi and animal cells. In a process called **precision fermentation**, microbes can be given special instructions to make useful food ingredients, such as proteins, vitamins, or natural flavors. For example, the red color in some plant-based burgers comes from a protein made by yeast during precision fermentation. These ingredients are usually added to improve the taste, texture, or nutrition of plant-based foods. Making them in large amounts is currently difficult and costly, but they can still play an important role in building better alternatives to meat.

Insects

It may sound strange or even a little unappetizing, but in many parts of the world, people already eat insects like crickets, grasshoppers, or mealworms. In fact, over two billion people include insects in their regular diets [3]. Insects are full of protein, and many also contain healthy fats, fiber, and important vitamins and minerals. Compared to farm animals, insects are much easier to raise. They need less land, water, and food, and they produce a lot less greenhouse gases. A big challenge is that many people—especially in Western countries—feel uncomfortable about eating bugs. To help with this, companies often use ground-up insects that are blended into foods, so they are less visible. Today, insect-based powders or flours are being added to snack bars, pasta, and even burger mixes. Some scientists are exploring ways to grow insect cells in bioreactors, similar to how cultivated meat is made, which could reduce costs and make them easier to use.

HYBRID FOOD PRODUCTS: WHY MIX AND MATCH?

Each alternative protein source has something good to offer—but no one source is perfect on its own. Plant-based products are usually less expensive than other options and can be made in big batches, but they do not always match the taste or texture of real meat. Cultivated

meat may taste just like the real thing, but it is still very expensive to produce. Mycelium has a good, meaty texture, but its flavor is strong and not very meat-like. Insects are nutritious and **sustainable**, but not everyone wants to eat them.

What if we could take the best parts of each alternative protein and combine them? That is the idea behind **hybrid food products**—new types of foods made by mixing different alternative proteins (Figure 1) [4]. For example, scientists might blend plant proteins with small amounts of cultivated meat to improve the taste and nutrition while keeping costs lower. Or they might combine mycelium with plant ingredients to create a meat-free burger with better texture and fewer additives (Figure 2). Even some regular meat products are becoming hybrids. Some companies are reducing the amount of meat in sausages or burgers by replacing part of it with plant protein or insect flour. This can lower the environmental impact while still keeping the flavor that meat-eaters enjoy.

SUSTAINABLE

Using resources in a way that protects the environment and makes sure there is enough for future generations.

HYBRID FOOD PRODUCTS

New foods made by mixing different protein sources to create better taste, texture, nutrition, and sustainability.

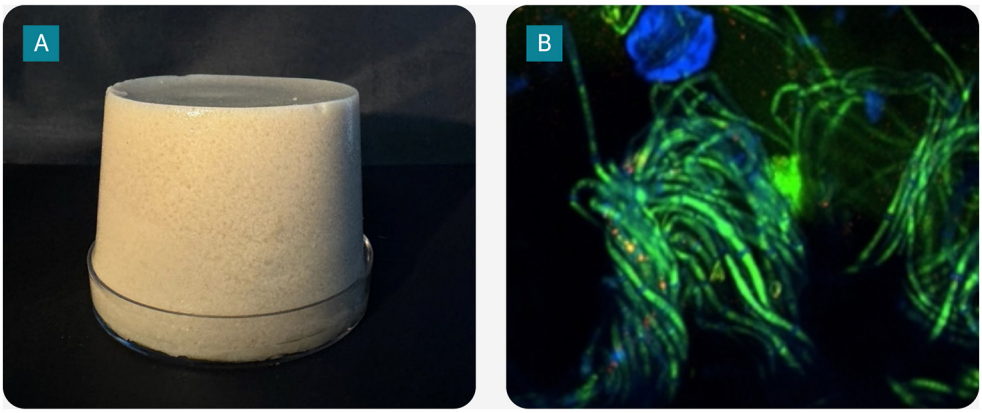

Figure 2

(A) A simple hybrid product prepared by blending gellan gum (from precision fermentation of microbes) and proteins obtained from mycelium fermentation. You can see that it looks kind of like a block of tofu. After adding the appropriate flavors and colors, these hybrids could be used to create meat analogs. **(B)** A view of this hybrid product as seen through a microscope, with proteins stained green and sugars called polysaccharides stained blue.

WHAT MAKES A GOOD HYBRID FOOD PRODUCT?

Designing hybrid food products is tricky. Scientists must think about taste, nutrition, texture, safety, and what people are willing to try. By mixing ingredients in smart ways, they are getting closer to building better foods. Here are some of the biggest things scientists think about when designing a new hybrid food (Figure 3).

Making It Tasty and Familiar

Even if a food is better for the planet, people will not want to eat it if it smells weird, feels mushy, or has an unusual color or taste. That is why scientists pay close attention to the sensory properties of a food—how it looks, smells, tastes, and feels in your mouth. Plant-based ingredients can sometimes have bitter or "beany" flavors. Insects can add a gritty texture or a strong smell. Cultivated meat and mycelium might help with flavor or texture but can be harder to

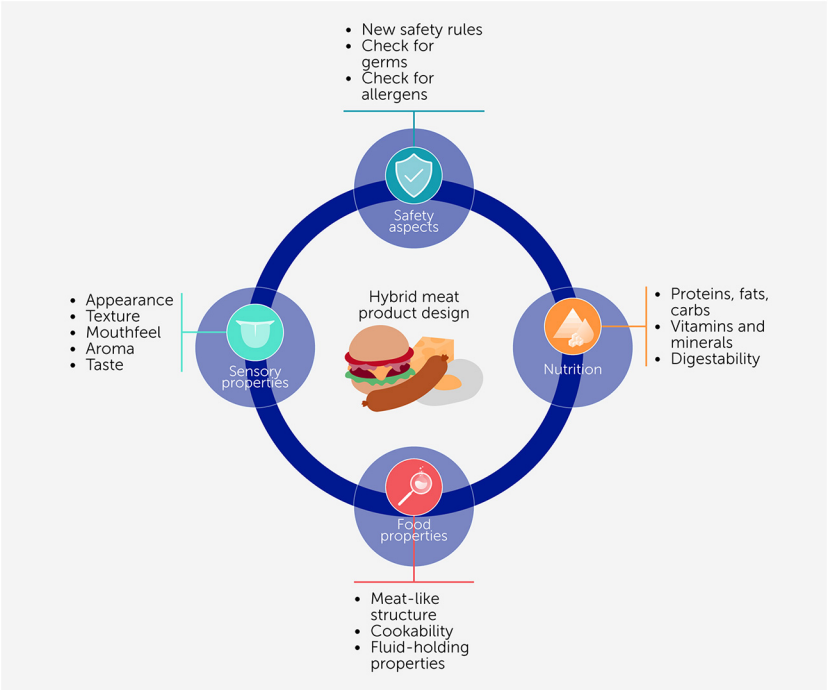

Figure 3

Several factors must be considered when designing hybrid meat products, including food properties like whether they have a meat-like structure and cook up well; sensory properties like texture, aroma, and taste; nutritional content that is similar to real meat; and safety checks to make sure the products will not harm people.

produce. By mixing ingredients in just the right amounts, scientists try to match the flavor and feel of real meat as closely as possible. The goal is to create a hybrid food product that tastes so good that people forget it is not traditional meat.

Keeping It Healthy

Protein is important—but it is not the only thing our bodies need. A good hybrid food product should also have enough vitamins, minerals, and healthy fats. Real meat is a strong source of nutrients like iron, zinc, and vitamin B12. Some plant-based products fall short on those, so scientists must balance the ingredients carefully. There is also a concern that some meat alternatives are ultra-processed—meaning they contain lots of added ingredients and are made using processing steps that change the food a lot from its original form. This kind of processing can sometimes make foods less healthy. Hybrid food products might help solve this problem by reducing the need for extra flavorings or ingredients that help the food stick together, especially if more meat-like ingredients such as cultivated cells or mycelium are included to replace these other additives.

Getting People to Try It

Even if a hybrid food product is tasty, healthy, and safe, it still has to pass one last test: *Will people actually eat it?* That depends on cost, convenience, and how open people are to trying new foods. Some people are excited to try plant-based or lab-grown meat. Others feel unsure—especially when they hear the word "insect". People who enjoy these foods can help spread the word and make others

more willing to try them. Food companies are working on packaging, advertising, and recipes that help people feel more comfortable with these new products. For now, many companies are focusing on flexitarians—people who still eat meat but are open to eating less of it.

FROM IDEA TO REALITY

Making good alternatives to meat is not easy. Hybrid food products show a lot of promise, but there are still important challenges to solve.

Ingredients like cultivated meat and fermented proteins are expensive to produce, and people will not buy these products if they cost too much. Scientists are working on ways to lower costs while also making enough to feed millions of people. Right now, hybrid food products are only made in small batches but, to have a real impact, companies will need to produce much more—increasing production without using too many resources or harming the environment. Safety also matters. Before any new food can be sold, it must go through careful checks to make sure it will not cause harm. That includes testing for germs, allergens, and substances that might block the body from absorbing nutrients. With hybrid food products, scientists also need to make sure that mixing ingredients does not create new problems. Safety reviews are important, but they can slow things down.

In the long run, hybrid food products could help feed a growing population while putting less stress on the planet. Getting there will take teamwork across science, industry, and society. The future of food might not look exactly like the past—but that could be a very good thing!

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CONFLICT OF INTEREST: DM serves on the scientific advisory board of several food companies, including a plant-based cheese company, a tempeh company, a cannabis edibles company, and an eye health company. As part of his services, he may receive shares in these companies. He also has some patents on the development of colloidal delivery systems for bioactive agents. He has received funding from the federal government and non-profit organizations to carry out research on plant-based foods. He has also written several books on next-generation foods that include a discussion of alternative proteins. DK declares that the research was conducted in the absence of financial relationships that could be construed as a potential conflict of interest. He has received funding from the federal government and non-profit organizations to carry out research on cell-based foods. He has also edited several books on cellular agriculture and sustainable materials.

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YOUNG REVIEWERS

ATHARV, AGE: 12

A curious and imaginative 12-year-old with a love for stars, stories, and science. Equally drawn to books, building things, and big questions about the universe. Calm yet adventurous, thoughtful yet playful, always exploring the world with wide eyes and a creative mind. Whether sketching dragons, designing paper airplanes, or decoding constellations, this young dreamer blends wonder with logic and magic with meaning, finding inspiration in the night sky and joy in every small discovery.

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