
XPRIZE
FEED THE
NEXT BILLION
ASPIRE
ALTERNATIVE PROTEIN:
THE STATE OF PLAY

When it comes to human flourishing, there is much to celebrate. Living standards in the West, and increasingly all over the globe, have skyrocketed over the past century. Despite some lifestyle-induced health issues, humans are overwhelmingly better fed, healthier and safer than they have ever been before. Calorie consumption, in addition to necessary (but hard to produce) nutrients and minerals like salt, is so common as to be unremarkable household items. Fresh fruit and vegetables, proteins, fats, and carbohydrates are all available in any metropolitan area. Indeed, many of them are now only a digital click away.

When we look back at the time our ancestors spent, or the danger they had to put themselves in, simply to acquire the basic items of survival, we cannot but be thankful for how miraculous the food system has become. The exponential rise in agricultural productivity, combined with medical advances, has caused the human population to skyrocket. In the early 1800s, nowhere in the world had a life expectancy of more than around 40 years old. That figure in the West has jumped up to nearly 70 years, and has continued to climb since then.[1] This longevity mirrors the global population increase: roughly an increase of a billion people per decade since 1960.[2] By 2050, the global population will reach an unprecedented 9.7 billion people!

But with every solution comes new challenges: and we are heading towards an unprecedented one. The consequences of feeding all of these people will push our problem-solving to the limit. Already, our earth is under enormous strain. At one point in time, the Victorian polymath Thomas Henry Huxley thought that the major ocean fisheries were so teeming with life that they could never be emptied.[3] Yet even today, at a population level of only 7.9 billion, we see a genuinely catastrophic decline in fish stocks. What's worse, industrial fishing practices result in a mass increase in maritime destruction and plastic pollution. We also imagine that the world outside our window is teeming with animal life. Last year, a report by the WWF showed that wild animal populations have plummeted by an astonishing 70% in the past fifty years.[4] Our vision of a world abounding with elephants, tigers, lions, and orangutans sounds more like a fairy-tale. In reality, the vast majority of the earth's animal biomass comprises about five creatures: humans, cows, pigs, sheep, and chickens.[5]

These problems are the consequences of the pressures of population growth on food systems, and we have been aware of them for a while. People have already been working on solutions, such as adopting a plant-based diet, compelling governments to institute better environmental and ethical protections, and encouraging people to consume more local, natural produce. Though all of these efforts should be praised and continued, it is doubtful whether they can provide sufficient solutions for this problem. It is tremendously difficult to install the mass adoption of veganism, many governments do not respond to democratic pressure, and local produce may not be able to provide sufficiently for such a growing population. They certainly give reasons for cheer, but they must be folded into a bigger strategy than what they are today.

XPRIZE Feed the Next Billion is a $15M competition incentivizing teams to produce chicken breast or fish fillet alternatives that replicate or outperform conventional chicken and fish in access, environmental sustainability, animal welfare, nutrition, and health, as well as taste and texture. Opening up the competition to cell-based and plant-based contenders, XPRIZE Feed The Next Billion is hoping to radically increase the horizon for protein production and biotechnology. In other words, what we used to get from farming and fishing, we will soon be able to grow at scale in food production facilities.

UNPACKING THE SOLUTIONS SO FAR

We've seen how much damage to the biosphere is caused by human population growth. Even though we are certainly heading towards a difficult time, let's take a moment to see what many of the successful solutions have been to mitigate some of the worst effects of this problem.

The first possible solution is adopting a plant-based (or 'vegan') diet. In recent years, the market for plant-based food options has increased exponentially. Part of this seems to be driven by consumer's increased awareness of the environmental havoc caused by eating meat. But it also derives from the growing consciousness of the importance of eating a diet that is predominantly based on fruits, vegetables, and other whole food plant sources. For many, this has led to the decision to totally reject any proteins derived from animal or fish sources. It seems that around 3% of the United States population follows a vegan diet, according to one major Gallup poll.[6]

The adoption of plant-based diets may lead to better health, but is it really the ideal lifestyle for human nutritional needs? While some think it would be a massive improvement for the majority of people living on earth, other studies show that there could be risks of micro nutritional deficiencies like calcium.[7,8] Another problem is that we don't really know whether it has the potential for mass adoption. Although it has increased significantly in the past few decades, it isn't clear whether this trend can continue. Is there a real prospect for triggering genuine change in food systems? It seems distant. We may be at 'peak vegan' already - and we are nowhere near solving the problem. Whilst there are certainly exciting moves towards the proliferation of vegan protein, the quality and texture of these products are not quite there to convince mass swathes of people - yet.

The second possible solution could be putting pressure on governments to stop these harmful practices. This could be stopping the over-use of antibiotics or animal cruelty, taxing (or banning) single-use plastics, encouraging a diet richer in fruits and vegetables, monitoring and preventing overfishing, or some other combination of all of them. Certainly, all of these possibilities should be explored and implemented. But there is a limit to what governments can do, even in the democratic world. For many countries with more authoritarian regimes, public pressure on government decisions is very limited. Also, many low-income countries are still battling poverty. This means that there are moral issues about whether their food industry should be impaired because of environmental sustainability. When it comes to starvation, there are no easy answers about balancing human life and environmental destruction.

Another option is encouraging people to buy and consume local produce. It is hard to conceive of any major downsides to eating from local farms on the whole, although the economies of scale mean that traditionally produced food might be less affordable for those on low incomes. Yet whilst returning to a world of local produce might sound fantastic, the practicalities of the issue may turn out to be a little bit more difficult. Even if we could do it, it is not quite clear how such a strategy of downgrading production would be able to feed and sustain the next billion people.

We've seen how these three main solutions are what's on offer to manage changing food systems. We shouldn't underestimate or undervalue how important these contributions might be. Consuming less of a Standard American Diet, buying locally, and encouraging governments to prioritize good, safe and humane farming practices are probably great things to do. But can they really carry humanity into the future, especially with growing demand from population growth? Food and environmental systems are at a critical point already. They can't take much more. We need to think of how human technology and innovation can play a role in saving the world from this problem.

THE PROBLEMS

Writing in the year 2021, it is hard to make sense of all the factors that have led to this environmental devastation. In one sense, it is nothing less than the compounded result of over a hundred years of industrialization, pollution, overpopulation, demand for resources, urbanization, and decline in nutritional yield. We are not only struggling to feed the world's population in the present, but the quality of the food that we do have is deteriorating with every passing year. This is partly connected to the profit-seeking models of food production, which exhaust and degrade the soil — leading to the increasingly poor quality of naturally occurring nutrients.[9] All in all, the problems in our food systems are enormous.

The situation is not heading towards improvement. Previously, most of the consumption of key animal proteins was taking place in the Western world. Today, as the developing world becomes wealthier, this is rapidly changing. Over just the next ten years, the global consumption of meat is likely to grow by around 12%.[10] Combine this growing demand from industrializing countries with a human population that is also predicted to hit 9.5 billion by 2050.[11] These future individuals will want their animal protein too. Can the food system support this new pressure?

POULTRY

By far, the most widely consumed protein globally is chicken. It is hard to imagine that the bird wasn't always eaten so often, but it's true. A hundred years ago, only around 6 billion chickens were slaughtered each year across the world. Today, that figure has skyrocketed to around 66 billion.[12] In the United States alone, the annual turnover of chickens for meat is approximately around 9 billion.[13] And when we look at future markets for chicken meat, such as in Asia, we are expected to see even more growth in chicken consumption. That is a colossal number of birds.

In a strange way, things could be worse. Unlike other animals, chicken production uses much less geographical space. Largely as a result of their cramped conditions – but also by nature of their small size – they put much less pressure on land resources than cattle or sheep. However, poultry meat that is produced in battery conditions (where the animals are packed tightly together and can't move around) has terrible long-term implications from a variety of perspectives – especially for the chickens themselves. Let's take a look at some of the major problems with intensely raised chicken on our health, our food systems, and our environment as a whole.

First and foremost, chickens, along with pigs, suffer greatly from being raised in factory farms. The welfare allowances for chickens labeled 'free-range' are often minuscule – perhaps only a tiny bit more room in a cage than those raised as battery hens. They are truly 'free range in name only.'[14] The vast majority of them are raised in an environment in which they barely have space to turn around or even stand up. Intensive production has caused them to become several times bigger than they were even a few decades ago. This increase in size helps bring them to market in less than two months.[15] One consequence, however, is the increased bone, immune, and heart problems that they get from carrying far too much weight. Though this results in productivity and efficiency gains in terms of human protein, the consequences on an ethical level are decidedly more mixed.

There is a second and far more worrisome consequence of raising chickens in bacteria-filled industrial conditions. Animals grown in intensive farming practices are often so sick that their farmers pump them with antibiotics just to keep them alive to the point of slaughter. There are obvious health concerns about eating meat so full of antibiotics. But the real danger is that global farming practices raise the specter of worldwide antibiotic resistance. This happens when bacteria manage to develop resistance to the antibiotics, which would normally destroy them. It is not possible to overstate the dangerous consequences of this happening. Without antibiotics, modern medicine as we know it will cease to exist. People will start to die of everyday health ailments, from routine surgeries to common infections, that have been eradicated from life as we know it. Imagine cutting yourself whilst on a hike and knowing that, if the cut got infected, your life might be at risk.

Contemporary poultry farming simply isn't justifiable in the long term. If we could innovate our way to abundant, lab-grown protein, whether through cell cultivation or plant-product, all of these problems would inevitably disappear. Risks of antibiotic resistance likewise would collapse if these animals were not pumped en masse with these chemicals. Cheap, abundant, and fulfilling synthetic protein sources for modern humans could ensure optimum nutritional intake for people of all ages across the world.

FISHING

The 2021 documentary Seaspiracy ignited a global conversation about the devastating consequences of overfishing on our oceans. For many, it represented a real shock to the system. In the not-too-distant past, people genuinely thought that the ocean was so abundant that it could never run out of fish. Entire civilizations, like pre-modern Japan, consisted in large part from the fruits of the sea. Even today, many coastal communities sustain themselves predominantly on the bounty of the ocean.

In the past half-century, however, things have taken a dramatic turn for the worse as the state of the world's oceans enters a period of transition. Only 13% of our oceans are now considered to be relatively untouched wilderness.[16] The effects of the fishing industry and climate change on land are causing massive amounts of coral bleaching, pollution, acidification, and warming water. Massive amounts of the Great Barrier Reef, perhaps the most beautiful maritime ecosystem on earth, are now bleached because of human-induced temperature changes.[17]

How can we make sure that our oceans remain healthy and sustainable for both future generations and the wildlife itself? There are three major issues: overfishing, destruction of ecosystems, and plastic waste. Let's examine them in closer depth.

Firstly, there is the problem of overfishing. Fish stocks have plummeted in the past few decades. Many marine fisheries worldwide are fished at or beyond sustainable catch levels, and most of the well-known types of fish are the most seriously affected.[18] Many cod stocks, even after having somewhat recovered from overfishing, are now back to being considered endangered. Tuna fish – one of the most popular fish in North America – are at such unprecedented low stocks that at least one-third will go extinct if fishing trends continue.[19] Many smaller types are also under such strain that they will be extinct within our lifetimes. Our staple, everyday types of fish will be wiped out if we don't change course. And 'sustainable' fish are often hardly sustainable at all. There is much evidence that these labels are misleading, and they often reflect practices that are not sustainable, ethical, or environmentally friendly.[20]

Secondly, the major consequence of overfishing is the long-term destruction of maritime ecosystems. Not only are the fish themselves being over-hunted to extinction. The ecosystems themselves get destroyed in the process. The introduction of advanced sea trawlers has led to the corollary destruction of many times more wildlife than was previously destroyed in small-scale fishing of the past. Trawlers pitilessly catch and destroy birds, sea turtles, and sharks as the unintended consequences of industrial fishing practices in open-ocean fisheries.[21] As Jonathan Safran Foer noted, if you are served one plate of sushi, you should imagine a plate five feet in diameter of fish, birds, turtles, and other marine life which was killed and dumped back into the sea to get that meal.[22] Even more distressingly, Western governments heavily subsidize these practices - often by up to $35 billion a year - which provides a financial incentive towards fishing at overcapacity.[23]

Thirdly, there is a major problem of pollution and plastic dumping. In fact, every year about 12 million tons of plastic are dumped into the world's oceans.[24] This represents the equivalent of nearly three Empire State buildings, just of plastic waste, into the water. Almost all of this plastic simply doesn't biodegrade. In fact, of all the world's plastics, only about 9% get recycled.[25] In the Pacific Ocean, for instance, there is a garbage patch that has grown to 1.6 million square kilometers. Although much of this is connected to generally poor waste practices on land, one major culprit for plastic waste is refuse from the fishing industry. Much of this is 'ghost gear' or abandoned and lost fishing equipment. These discarded nets, ropes, and lines cause severe damage to maritime ecosystems.[26]

The oceans becoming filled with trash is obviously undesirable on its own terms. Other wildlife suffers enormously from being caught in – or consuming – these plastic waste products, which often lead to sickness and death. As ocean pollution increases, the consequences of microplastics in the food system continue, too. And whilst there is some debate about exactly what the effects of this will be for both human and non-human health, there is a wide consensus that it is a very concerning problem.

HOW WE SOLVE IT

There is one strong contender for a realistic and achievable solution to this problem: alternative protein, be it plant-based, fermentation enabled, or cultured from animal cells in a laboratory. In the past decade, consumers have seen a transformation in available alternative proteins. The production and sale of novel and alternative burgers, sausages, and chicken pieces has grown and is likely to continue into the future. This partly reflects consumer demand: people are much more conscious of what they eat and how it impacts the environment than they were even only a few years ago. Even just looking back a decade, veganism seemed an impossible way to live. Today, meat-free options are found in many places in the world. There is much wider availability of foodstuffs that were basically inedible within living memory.

There are two major sources of protein for these novel forms of protein. The first, plant-based, is already on our shelves - and doing exceedingly well. The second is that growing meat from cells in a laboratory has gone from science fiction to laboratory and now, in some parts of the world, actually to our plates. Many of our problems with food systems, especially in anticipation of a growing population, could be solved with either of these solutions.

The former, plant-based, is now a very common foodstuff. Vegans will recall a time in the not too distant past when anything like that was very difficult to find. Even vegetarian food was rare. Now, it is completely normal for there to be at least one vegan item on any menu. In fast-food eateries, this usually includes some kind of plant-based protein, like alternative burgers or sausages. The texture, flavor, and overall meat-like experience in these foods have become so much better than before that even meat-eaters are opting for them for ethical or environmental reasons.

However, this is not quite the end of it. These plant-based proteins, whilst making major inroads, are still far from perfect. The flavor is not quite there, even if it is increasingly approximating the taste of animal meat. Similarly, the texture still remains distinctly not-meaty, although foods like chicken nuggets are increasingly coming to resemble the traditional product. Lastly, the price is still not quite near optimum levels. Plant-based proteins are often more expensive than traditional options, and this is another disincentive for people who are looking to engage with a more environmentally-friendly food from doing so. There is still quite a long way to go to create the perfect, cut-like meat or fish substitute from plant-based proteins.

Alternatively, there are also competitive inroads being made with the cultured protein space. However, it is not quite ready yet. In 2013, the scientist Mark Post made headlines with the first lab-grown burger. Made from stem cells taken from animal muscle, the burger was the first of its kind. This fact was reflected in its price: around $280,000 for one patty of meat. It was clearly not ready for mass consumption. Even the richest individuals on earth would find it difficult to sustain a diet with the price of meat that enormous.

In Singapore last year, however, things have already begun changing. In a world first, the government has approved the first cultured-chicken nugget, which is now being served in the restaurant 1880. However, it still suffers from the same problem as the cultured beef patty: price. Each serving at the restaurant in Singapore is around $17; not completely unaffordable, but mostly out of the price range for daily consumption. Turning this product into something scalable, and thus ready for mass consumption, will be the natural next step for companies producing alternative proteins like these.

A similar process is happening for cultured fish protein too. In the spring of 2021, a Hong Kong start-up managed to develop lab grown fish fillets for commercial consumption. According to the chefs cooking it, the product could not quite capture the taste and texture of natural fish - yet. But it is well on its way to reaching the necessary flavor and consistency that consumers will demand if cell-grown protein is to be as successful as regular meat.

As we can see from these early trials, there is plenty of reason to be optimistic. The concept is no longer only within the realm of science fiction. But there are still significant challenges ahead. One is the financial issue: it is still simply too costly. The next is one about infrastructure: growing this food requires the same kind of technology used in cutting-edge biotechnology. Lastly, the energy input required is enormous and cannot be reduced quickly and easily. These commercial challenges are not likely to go away soon – unless human innovation can stimulate a way through.

Another major issue is that, even if we are able to manufacture cheap, delicious alternative meat, we don't really know the extent to which consumers would quickly adopt it, at least initially. Studies show that, whilst people may be relatively open to the idea of cultured meat, plenty still find the idea less palatable. In France, the minister of Agriculture only recently suggested on social media that the government will never accept the commercialization of cultured animal protein in order to protect traditional food from being taken over.[27] Perhaps one solution here would be to show people that the food they already eat is hardly 'natural' – industrial farming practices, with battery cages, growth hormones, and antibiotic use – are the farthest thing from our popular images of organic and pristine animals.

Lastly, another question for the roll-out of cultured protein is the question of religious prohibitions. One issue is about the exact nature of the flesh-meat itself. Is synthetic pork the same as traditional pork, and thus forbidden for the entire Islamic or Jewish world? What about a pork, chicken, and beef mixture? Does even one cell of a prohibited animal make that meat unsuitable, or are there other ways of thinking about it? These are all very difficult questions that will have to be solved in the next phase of agricultural development.

But all innovations will bring with them certain problems and teething issues. It is simply part of growing into new spaces. Whilst there are all of these obstacles ahead, the potential for these synthetic proteins is too important to delay. Researchers note that negative views about cell-based protein do change after exposure to positive information.[28] The fate of our health and the health of the planet rests on human innovation driving a massive change in our food systems, even if there might be some teething issues around structural characteristics, consumer choice, price, and energy.

CONCLUSION

Can the earth be healed from mass over-exploitation of its seas, rivers, and pastures? The answer is yes. Human technological development has clearly brought unprecedented destruction to the environment. But this is not necessarily just a modern problem. Scientists have long argued that the megafauna which once roamed the earth – mammoths, saber-toothed tigers, woolly rhinoceroses – were all hunted to extinction by modern humans tens or hundreds of thousands of years ago. This was at a time when homo sapiens had only just invented stone tools. Given how much damage was done with flint spears, it is no surprise that in our petroleum age only 2-4% of mammals on earth are wild.[29]

Unlike in the past, however, technological innovation can take us to an entirely new place – one of infinite, abundant, and ethical protein. With the end of traditional animal agriculture, we have the tools for creating a new vision of a flourishing earth. One exciting example of this possibility in action is the expanding movement to 'rewild' the planet – turning shrubland, wasteland, old agricultural areas, and even deserts back into forests and woods. This form of restoration is already growing public consciousness on what great ecological treasures we've already lost. But it is also a strategy towards getting it back.

However, there is only so much 'rewilding' we can do in a world where nearly eight billion people (and nearly ten billion by 2050) continue to need and want protein. There are barely enough resources to feed those living humans already. We have traded oceans teeming with life and replacing them with millions of tons of plastic bottles and fishing nets. The Amazon rainforest, the most densely biodiverse region on the planet, is collapsing under the weight of destruction from cattle ranching and soy production. Whether cell or plant-based, synthetic protein offers a major hope to change this situation for the better.

Perhaps we are on the cusp of the greatest transformation in the human diet since the invention of large-scale agriculture around 9,000 years ago. This farming revolution catalyzed the change for Neolithic humans and turned them from hunter foragers into settled civilizations. What happens after this next food revolution is still a mystery. We simply have no idea what a world of cheap, abundant proteins and a rewilded planet might look like. One thing we do know for sure, however, is that the earth – and human history – will never be the same again.

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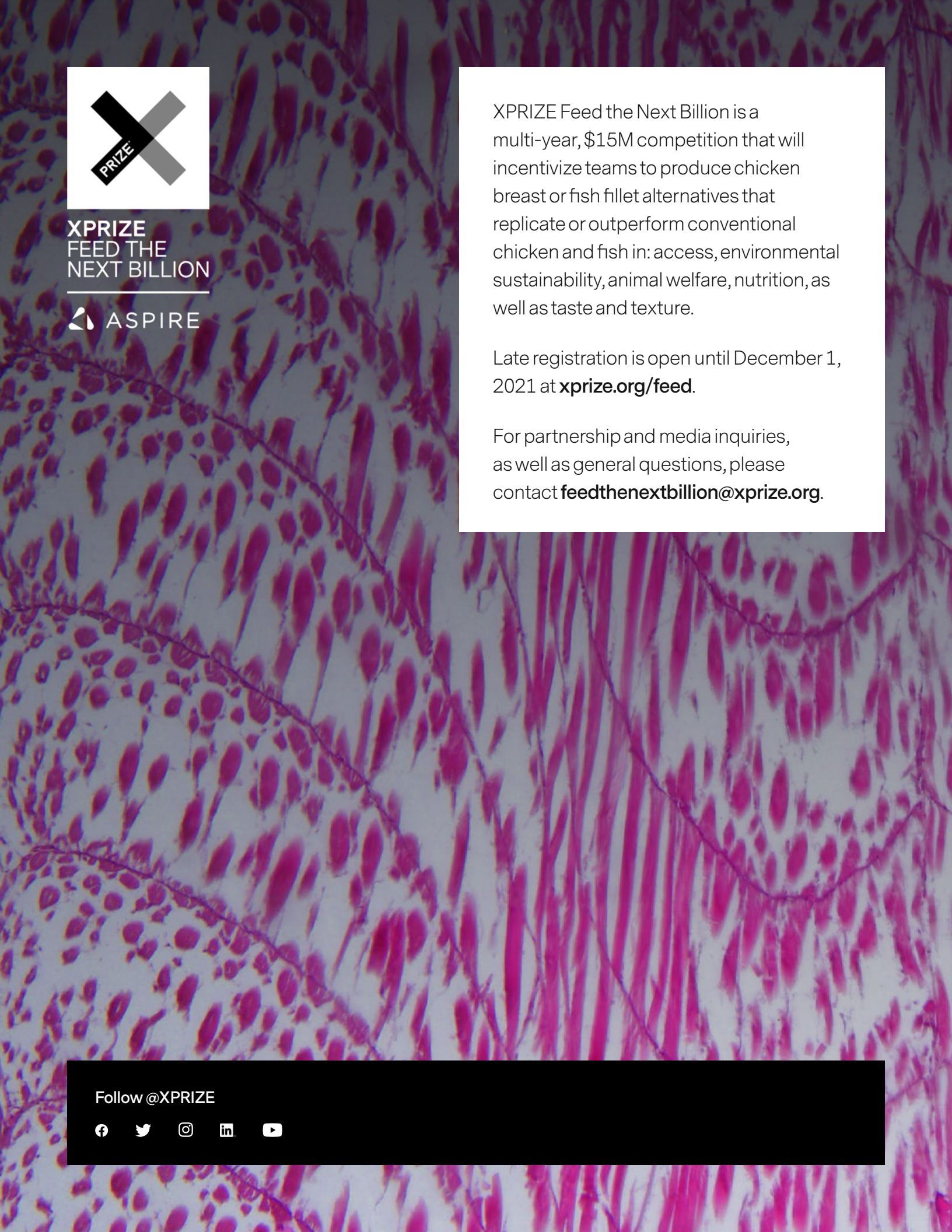

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Late registration is open until December 1, 2021 at **xprize.org/feed**.

For partnership and media inquiries, as well as general questions, please contact **feedthenextbillion@xprize.org**.

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