

URL: <https://stvp.stanford.edu/blog/videos/food-fight-to-turn-back-climate-change-entire-talk>

Make beef out of plants instead of cows and you can begin to save the planet. That's what inspired award-winning scientist Patrick Brown to leave his professorship at Stanford University and found Impossible Foods. In conversation with Stanford Professor of the Practice Tina Seelig, Brown describes how his singular passion for impact prompted him to leave academia and become a food-tech entrepreneur.



## Transcript

- Now Impossible Foods, for those people who aren't familiar, makes meat and dairy products totally from plants.. So the idea is it is a much smaller environmental footprint than any meat that is produced from animals.. And their first product, the Impossible Burger, is sold in more than 40 restaurants, and the company's-- 200, more than 250.. - Oh, my goodness, news.. - Probably 300 by now.. - How many, 300? - Probably 300 by now.. - Fabulous, great, and tomorrow it'll be 500, okay.. And it is privately held, and investors include Khosla Ventures, Bill Gates, and Google Ventures.. So pretty impressive.. Let's dive in and get some details..

Maybe you can just start out by telling us about what is the Impossible Burger? - Okay, well, first of all, the best way to get the answer is go to the event afterwards.. (audience laughs) - (laughs) And try it.. - Yeah, it's a burger that is intended very deliberately to satisfy meat lovers.. That's the only consumer that we've ever been designing our products for.. And it's made entirely from plant ingredients.. But it basically delivers the full sensory experience that burger lovers want in terms of flavor, aroma, the cooking experience if you're cooking it.. But it's made entirely from plants.. And it has a, it's environmental footprint is a tiny fraction of a burger from a cow.. So we've done a very detailed and audited analysis.. Producing it involves 1/8 the greenhouse gas emissions, uses a 1/4 of the water, and less than 1/20 of the land area that's required to produce the same thing using a cow, which was motivationally a very important part of it..

But what matters to the consumer is that it's absolutely delicious and craveable.. And don't take my word for it, go to Vina, and decide for yourself.. - Okay, well, I'm really curious.. We've got a lot of people who are engineers in the room, and this all sounds very great from a marketing consumer perspective, but let's talk about the technology.. What has made this such a challenge to do? Why are other people not doing this, and what are the biggest hurdles that you have to face in making this happen? - Wow, okay, that's a lot of questions.. So, I guess I can't really explain why other people haven't done it, except that I think the entire space of possibilities for doing transformative things in the food system is vastly underexplored relative to its potential and its importance.. And I think there's been very little real innovation in the traditional food industry.. And the notion that.... So we started with the idea that it should be possible to make meat, and by meat I mean, I define it in the way that consumers define it, the flavor experience, the cooking experience, the whole sensory experience, nutritional value, and affordability, and so forth.. To make meat better in all those measure than a cow can do it, or than the existing technology can do it..

That basically, that the technology that we've been using up to now to make meat is fundamentally limited, and it's also completely unsustainable.. But it's just a technology problem.. We've kind of conflated the products with the way we make them.. We use animals to make these products.. But the value to consumers, and we actually have data on this, has nothing to do with the fact they're made from animals.. You don't love meat because it's made from animals.. You love it in spite of the fact that it's made from animals.. And using animals at technology is fundamentally limited.. Cows did evolve as a meat production technology.. They were incidentally taken advantage of as a meat production technology..

That if you approach the problem as saying, we have to deliver a particular kind of sensory experience to consumers, and nutritional value, and versatility, and affordability in a particular form factor, and blah, blah, blah, blah, blah, but we wanna do it with a blank slate, basically, and with the goal of massively reducing the environmental footprint, and we want to do a better job than the existing technology can do.. Well, that's completely what's, that makes perfect sense to me, anyway.. And

it's kind of like the same thing with transportation 200 years ago.. 200 years ago, people, if you said, I'm gonna make the cart move faster without using the horse, they'd think you were crazy.. Because people conflated the particular way they made the cart move with the kind of universe of possibilities.. But when you step away from that, you realize that actually you can avoid all the limitations of the existing technology, or you can get rid of the limitations of the existing technology, and there's vast possibilities for improving it.. So anyway, that's-- I love that analogy, honestly, about the cart and the horse.. I think that is so fascinating.. It's interesting to think, though, about how did you make this decision to do this, right? You were a professor here for 25 years.. You had a very comfortable job doing research..

What made you wanna leave to solve this problem? And what was the aha that you said, I need to go and leave academics to go solve this problem? - First of all, so I love my job, and I love Stanford, and everyone that I knew and worked with here.. But I never define myself as a biochemistry professor, or something like that.. It just happened to be what I was doing at the time.. And I always felt like I want to do the most important and impactful meaningful thing that I can do given the things that I know how to do.. And for a long while it was trying to develop a better basic understanding of sort of the fundamental mechanisms that keep cells alive, and how genes work, and stuff like that both as pure knowledge, and also because that's kind of like the foundation for being able to develop better ways of treating and diagnosing disease and so forth.. So I thought, okay, that's pretty impactful, and I was happy doing that.. But I, I had a sabbatical, and I had the opportunity to basically just step back from it, and ask myself, okay, what right now is the most important problem in the world that I can potentially contribute to solving? And I realized very quickly that the most important and urgent problem in the world, in my very strong opinion, full stop, is the destructive impact of our use of animals as food production technology, which not just according to me, but according to UN Environmental Programme and many other environmental scientists is by a big margin the most environmentally destructive technology on Earth.. So, okay, that's easy.. So that's the problem.. And it took me a while to come around to realizing that the solution involves starting a business..

In fact, when I got into that thought process, it was like the farthest thing from my mind.. But I realized that no one was taking this seriously as a solvable problem.. I went to the COP21 conference two years ago, and it was all these people who live and breathe climate change.. And not a word, I mean, I basically, I think, was the only person in the entire city of Paris who was talking about the animals in our food system as a major cause of climate change.. And yet, if you talked to anyone there, they'd say, yeah, of course, it really is.. But it was on no one's agenda, why? Because for billions of people around the world, the foods that we get from animals are such an important part of the pleasure of living that it's too much of a stretch to contemplate, basically, leaving those foods behind, even for people who live and breathe these kind of environmental issues.. And so you have this dilemma that billions of people, and rapidly increasing, demand for these foods, and the way we're making them is completely unscalable.. The magnitude of the environmental impact, don't get me started, but is humongous.. How do you solve that dilemma? You basically separate the things that people demand and desire, which is the functional properties of these foods, flavor, all the things that you love about those foods, from the way we make them.. And I felt like, okay, actually, if you do that, that's a solvable problem, and that what it enables you to do is, that it should be possible to do, is to create products that outperform in every way that consumers care about the products that we get from animals much more sustainably..

Basically, deconstructing the problem and making these products directly from plant ingredients.. And if we then just put them on the market, and let the market work, let consumers make the choices on us to make a product that's so good that people choose it over the existing products.. But if we can pull that off, we solve the problem.. And at potentially a very fast pace.. We set our target as, basically, this is our internal strategic target, we want to effectively completely replace the use of animals in food production technology by 2035.. And I think that the only way you can do that, the only system fast enough to make that happen is the market, and products that outperform.. - So I know that other people are tackling this in other ways.. For example, trying to grow meat in the lab, right? Actually not using an animal to grow the meat, but doing it in a laboratory setting, you're growing muscle.. So what do you think about that as an alternative? - Couple things.. Well, first of all, I feel like anyone who is seriously trying to tackle the same problem that we're working on, as far as I'm concerned, I wish them all possible success..

And as far as from a scientific standpoint, I think it's really a terrible idea.. (audience laughs) Because the problem is that for fundamental reasons, there is just absolutely no way to make it economically competitive with the incumbent system.. I would liken it to, I would say, an easier way of doing it, in vitro, growing animals from stem cells to size and blah, blah, blah, is a harder way of doing it than if you start with a fetal calf, you knock out its immune system, because these cells don't have an immune system, and feed it intravenously for its entire life in the ICU.. That's easier than taking a further step back and you have to create the fetal cow from stem cells and then grow it up, and still in the ICU without an immune system.. So that's just I think.... But I hope I'm wrong about this, but I know I'm not.. (audience laughs) - [Tina] Well, I guess time will tell, right? - I also think that there's a fundamental fallacy here, which is that the problem was the failure to disconnect the food from the way we've been making it, not fully disconnecting it.. And an analogy that I would make is if 200 years ago, people had made the same mistake, they would've said, okay, the way to kind of replace the horse in transportation is we'll culture horse muscle cells, and we'll hook them up to gears and pulleys, and that's new and improved transportation system.. Because you haven't recognized that no, there's nothing about the horse that you need for this.. And there's nothing about the cow that you need for making meat..

- So what do you need, okay? So what makes this burger, which I've had a chance to try, and what makes it so unique as

opposed to other sort of veggie burgers? Why, what is the secret sauce that makes this taste and feel just like a regular burger? - So I'm terrible at give simple answers.. (audience member laughs) The basic secret sauce is that we have an amazing group of scientists and engineers, a very large group who have worked for years on this problem and started out basically saying step one, in order to make meat that's better than a cow, first we have to really understand how the cow does it.. What is the, so to speak, the molecular mechanism of meatiness? Understand how meat works as a food in fundamental terms, so that then we could very deliberately find much more sustainable set of ingredients to deliver those functional properties by understanding what the underlying biochemistry is.. So in a sense, the secret sauce was, I think, we approached this the way it should be approached, which is a fundamental scientific problem.. And I'll just say, we spent probably 1,000 as much money on fundamental research aimed at improving the food system.. I mean, just treating it as a fundamental scientific problem than we do on cancer, but the impact on the world is vastly greater.. Even if you just look at deaths from malnutrition, or bad nutrition and so forth are greater than all the deaths from cancer, but that's not even concerning the environmental impacts, and all the other health impacts, and so forth.. And yet, there's been virtually no research on this.. So the secret sauce was basically respecting this as an important scientific problem and doing it hard.. But actually, ingredient-wise, we had to find proteins that performed as major muscle proteins do, not moving animals around, but in terms of what happens when you cook them..

And it's important for textural transformations, and juiciness, and stuff like that.. And probably the single most important kind of headline thing was we discovered how the molecular mechanism by which the flavor of meat is generated, and not just beef, but all meats.. And it turns out that it's basically because meat has, everything we call animal tissues have very high levels of a molecule called heme.. Heme is the molecule that makes your blood red, that carries oxygen in your blood.. It's iron-containing.. It's the thing that makes meat a great source of iron.. And it's basically found in every form of life.. And without heme, you would not be able to benefit from oxygen in the air.. So basically, when your body takes in some biochemical way advantage of molecular oxygen from the atmosphere, virtually always it does so by means of heme as a cofactor.. Okay, that's too much in the weeds on heme..

But basically, animals use a lot more oxygen than plants, and bacteria, and stuff like that in general.. And so to manage all that, they have hundreds to 1,000 times more heme than a typical plant does.. And the very high abundance of heme is what sets meat apart in terms of flavor, and aroma, and so forth, and that's because besides being involved in all of these oxygen transactions, heme is a great promiscuous catalyst of chemical reactions.. And so the chemical reactions in meat that take all the simple nutrients like fats, and amino acids, and vitamins, and sugars that are found in every living cell, but turn them into that unique explosion of flavor and aroma are catalyzed by heme.. That was something that our team discovered.. Amazingly, something that I would've thought in retrospect, how could this not be already widely known given how meat is so important to people, and the flavor of meat is so distinctive, and heme is just like in there staring at you.. But it had never been discovered before, and so we're able to get patents on it, and all of that.. - Could I take heme and put it in something else and give that same experience? - Yes.. - I mean, why do I have to create the entire meat experience? Can't I put it in a carrot? (laughs) - Yeah, okay.. A very good question..

- I mean, and then have the same experience of meat, and say, wow, the carrot becomes more appealing.. A-peeling the carrot, I like that.. - The answer.. (audience laughs) So okay, so it turns out that heme is also important for, it's the critical, for fish flavor, it's also the critical catalyst.. It's pretty much, except for dairy products, I think, the unique flavors of things we get from animals are largely unique because of heme.. But you get different flavor profiles.. And so you can take heme and put it in a different mixture of other kind of basic nutrient molecules, biomolecules, and get different flavor profiles out of it.. I mean, the reason why fish taste like fish and terrestrial animal meat taste different from that is basically because fish has, fish have these polyunsaturated fats that they get from algae, and heme catalyze the reactions that turn those into flavor molecules, and aroma molecules, and stuff like that.. So the different precursor is in fact, the flavor outcome.. And this is actually, for the future for us, I think a great area for exploration is right now the space of possibilities of meaty, animal flavors that are out there are just defined by the animals that happened to have been domesticated, or whatever, or even just happen to live on Earth..

But once you kind of know what the basic flavor chemistry is like, now that whole space is open for exploration, and my guess is that we'll be able to create some really great, amazing, interesting flavors in that broad space with new substrates.. Carrots I'm not sure (interview laughs) are going to be the best choice, but it would be a very interesting experiment.. I think you need a bunch of small molecule precursors.. Actually, there's even an interesting thing, one of the major ingredients in carrots in combination with heme produces the flavor of egg yolk.. So that's-- That's the carotene.. - So yeah.. So anyway, it wouldn't be a crazy experiment to do, actually.. - Yeah, we could do that.. - Actually, okay, we gotta do that.. (audience laughs) - We gotta do that, okay? - Carrots, heme..

- [Tina] Okay, I'll come over and try it.. - Yeah.. - So what is your source of heme? Where do you get it from? - So we produce it using an engineered yeast strain that synthesizes its heme using the same.... This yeast strain can make its own heme, and it needs the heme that it makes to live its life.. We've turbocharged its own heme production machinery, so that it makes insane amounts of heme.. And we've also introduced a plant gene, because heme basically only works the way it's supposed to work when it's bound by a protein.. And we needed a protein that was essentially very functionally similar to the protein that binds the heme in animal tissue, in muscle, which is myoglobin, and we found one.. It's naturally found in the root nodules of nitrogen-fixing plants.. And we thought we might be able to isolate it by digging up the root nodules from the US

soybean crop, and isolating it.. Actually, on paper that seems like a good solution..

In practice it was, as we learned, painfully a completely impractical way of doing it.. And so we switched to producing it in yeast.. And that's a very scalable system.. And way more sustainable, and more food safe than producing it with cows.. - Okay, so I wanna flashback again.. I'm gonna go back in time.. - Yeah.. - You've got this idea.. You get this aha, and I understand you jumped on your bike, and rode over to Vinod Khosla's office.. - Don't think I jumped on it..

- That's what, well, okay, you got on your bike.. - Uh huh, yeah.. - I'm visualizing this, okay? You're like, oh, my gosh.. I'm gonna drive over to Vinod Khosla's office, and show him my pitch deck, and you walked out with \$7 million dollars.. - Yes, roughly, yeah.. - Roughly.. (audience laughs) - In that ballpark.. - So what did you say to him? (audience laughs) - Yeah, suitcase full of money, basically.. - What did you say to him, and what was it that got him so excited that he said, okay, I gotta do this? What can we learn from you? - I don't wanna speak for Vinod.. He might give a different answer for what it was..

I mean, basically, what I said to him was, and I should say, for business people here, the pitch that I gave him, in retrospect, was ridiculous.. (audience laughs) Because I had never been in the business world.. I had no experience with this kind of stuff.. And I had been introduced to Vinod by a scientist friend of mine who said, "Oh, Vinod will be very interested in this project," and blah, blah, blah.. So I basically, most of my presentation was about how hugely important this problem was to solve of we have to find a better technology than animals for producing these foods, because it's so insanely destructive.. And I absolutely believe it can be done, and I have some sketchy ideas about how it might be done if you give me the money.. And oh, by the way, the global market for these products is \$1.5 trillion.. (audience member laughs) And ever since then, I say this, but it's not a joke, it's true, that final slide gets closer to the front of the deck as I learn more and more about how business works.. (audience laughs) And I don't know at what part of that presentation he was sold.. I think he did care about the environmental impact..

I think the fact that I can look him straight in the eye, which I did, actually, and I said, I literally more or less said this, "I promise to make you even more insanely rich "than you already are (audience laughs) "if you give me this money." Seriously.. Because I felt like I'm not taking charity here.. I need the money that you're gonna give me, and I'm gonna try to accomplish something.. And my reasons for accomplishing it may be very different from yours, but you're gonna come out okay financially if we do this.. Anyway, so he was a good enough sport to give me the money.. - Great, I love the idea that, and it's something that we teach our students a lot, is fall in love with the problem, not the solution, right? So you presented him with a big, hairy problem, and you said this is a problem I care deeply about, and I'm committed to solving it even though the path might be somewhat circuitous.. - Yes, I think it was important that I could, the fact that I knew I wasn't bullshitting, actually, I think is really important.. I feel like I could look him honestly in the eye and say this is going to work out really well for your investors and so forth.. My reasons for doing it, like I say, are completely different.. I want to solve this problem and stuff like that..

But if it was gonna be a charitable cause, these guys wouldn't have invested.. So obviously, that was a big part of it.. But the determination, I think this is really important.. I don't wanna read Vinod's mind, but I think it mattered to him that I am completely determined to solve this problem.. I'm not gonna quit until we've achieved our mission, which is to replace this technology.. And he knew I was telling the truth because I was.. - So what does success look like to you? Paint a picture of what success looks like.. - Well, basically, it's that number one, we are no longer using animals as a food production technology.. Number two, as a consequence-- - Like at all, like they're gone.. - For all practical purposes..

- Like the food's gone.. - I'm not saying that some guy in Malawi may still be taking care of his goat.. (audience member laughs) No, seriously, I don't wanna be black and white about this.. But I'm saying, for all practical purposes, that technology is obsolete.. And actually, in a certain way, we're hoping that we can say a year from now that cows are an obsolete way to produce beef.. That we can demonstrably produce a better product than a cow.. But anyway, that's a bit off the track.. But success, we'll discuss what it looks for us.. Okay, that's the mechanism.. But the consequences are we should be able to, first of all, right now 45% of Earth's land area is, according to the International Livestock Research Institute, which is an NGO devoted to livestock farming, is actively in use, was actively in use in 2011 either raising feed crops or being used for grazing livestock..

45%, that's an area bigger than North America, South America, Europe, and Australia combined.. And we oughta be able to replace all the ingredients used in all the meat, fish, and dairy foods, not just the terrestrial ones, but meat, fish, and dairy foods worldwide using technology that we already are sort of aware of with about 2% of Earth's land area, which means that we will recover for other purposes, 40% plus of the entire land area of Earth, and that's huge.. And what could we do with it? Well, a lot of it used to be forest.. It used to be natural grasslands.. If we restored native ecosystems, we could potentially reverse the catastrophic meltdown in wildlife populations, which is almost entirely driven by the use of animals of food production technology, their exploitation, or habitat destruction, allow wildlife population to recover.. There's a catastrophic meltdown.. We have less than half as many living wild animals on Earth than we did 40 years ago overwhelmingly due to the use of animals of food production technologies.. So we could reverse that.. The other thing that's really interesting for people who are interested in geoengineering to deal with climate change is that the best technology that we know about, as far as I'm concerned, for removing carbon from the atmosphere is photosynthesis.. And if we allow the vegetation that was originally on that land 150 years ago just to recover to the state it was 150 years ago, we would pull out of the atmosphere,

and there's very good data on this, we would pull out of the atmosphere an amount of carbon dioxide that's equivalent to 15 years worth of greenhouse gas emissions at 2016 rates..

We could turn back the clock on atmospheric greenhouse gases.. You'd reach a new steady state, so it's not like you're just gonna pull all the CO<sub>2</sub> out of the air down to zero.. But you'll reach a new steady state and buy yourself a lot of time to find more definitive solutions.. So that's another thing that would happen.. We said early on that we would define our success by looking at satellite photos of the Earth, and looking at the recovery of ecosystems, and that's what success looks like to us.. - Great.. So I understand, I read about the fact that you were one of the first people when you were in medical school to say you wouldn't do tests on animals while you were in med school.. Do you do tests on animals now? - Well, I was the first person in my particular medical school to refuse to do it.. And I'll just say that pretty much every single medical school in the world in the meantime has realized that was a completely ridiculous thing to do and useless, so in the end I was vindicated.. Although, I was made to do some penance for bailing out on that..

- But I'm curious, do you have to work with animals? And do you have to test on animals? - Well, that's the question.. What you're referring to is in order to achieve our mission, we need to have products that are, both from a regulatory standpoint and from a consumer acceptance standpoint, demonstrably safe foods.. And from a regulatory standpoint in particular, FDA, and their counterparts in Europe, and other places, and so forth, essentially require that for new ingredients like the heme protein that we're using, you cannot get their sign-off on safety unless you do animal toxicology tests.. We tried, we started talking to the FDA five years ago, or something like that, and we put together what we thought was a compelling case, we and other experts, a compelling case for why we didn't need to do those tests to establish the safety of this protein.. To a biochemist, it's a no-brainer.. And to a toxicologist.. But anyway, but from a regulatory standpoint, they said no, you have to do these rat toxicology tests.. So we did.. And for me, that was a terrible problem because, I don't even wanna get into it, but for, as a model, as a scientific model for the types of things that they're used for, I think that most animal models are ridiculous.. And they're terrible..

And they give results that are not only not reliable, but they give false confidence in some case.. So that's one thing.. But I also consider it basically, from my perspective, unethical unless there's some absolutely compelling reason.. So I'm not like saying, never use animals.. Like if someone I loved, their life depended on me doing some test on a rat or something like that, I'd do it in a heartbeat.. So it's not like I'm categorical about this.. But for things that are unnecessary, I consider it absolutely unethical to use animals for these tests.. This was necessary, because if we're gonna achieve our mission, we need to be able to sell our product.. And in order to sell our product, we need the regulatory approval.. And in order to get the regulatory approval, we need to do these tests..

And by every measure in terms of the greater good for the world, this is what we had to do.. But we weren't thrilled about it, or I wasn't thrilled about it, let's put it that way.. - So I'm gonna open it up to questions from the audience in just a minute.. So please think about your burning questions.. So here you were, a scientist for 25 years, a research scientist professor.. What about that role prepared you to run a company like this? Did you feel like that was a nice training ground, or did you feel like you had to totally retool in order to do this? - It's hard to say.. I feel like the experience that I had at Stanford, I think was extremely helpful for it.. It's a little bit hard to parse it out, but I'd say you have to choose really important, really difficult challenging and interesting problems in order to be able to, first of all, for me to be able to be motivated to work on them, but also if you do that, if you can choose those kinds of problems, you can get amazingly great people to come join you and work on them.. So my lab was successful, I think, largely because the problems that we're working on were important, and interesting, and challenging enough that great people wanted to come work on them.. So that's one thing, I guess..

And definitely, my style compared to a typical business, I think is much more wanting to identify problems, and suggest, work with people to help them solve them, and suggest solutions, and stuff like that.. I'm not very good at the kind of top-down managerial type of thing that you need for businesses.. But fortunately, I know where to find them like Stanford Business School.. So that's another thing is that I feel like I definitely learned at Stanford what I'm good at and things that I'm very not good at.. And so that helped me understand I really need to fill those deficiencies by getting really great people to fill them.. I don't know, you also learn how to try to convince people to give you money, 'cause that's how you fund your lab and so forth.. And I guess something else which fortunately hasn't been called into use yet, but I'm sure will, is that when you're trying to do really hard stuff, and really do stuff that's outside the box and people aren't used to, you're gonna have a lot of doubters.. And I've had the experience when I was at Stanford, I wrote a grant proposal that I thought was, and I still do, the best grant proposal I'd ever written.. And when I got the review back, it was the worst priority score I had ever seen, not just on my grant proposals, but on any grant proposal.. (Tina and audience laugh) And I went ahead and did it, and it was a huge success..

And it was the best kind of overall thing my lab had done, and so forth.. So I feel like perseverance, I'd say, is another really good thing.. And that to do really interesting stuff, you're motivated because the goal is interesting, but you also have to do some really uninteresting stuff to get there.. Like there's a lot of these hard research problems.. It's really exciting when you get the results, but a lot of getting there is like doing very repetitive stuff, and so forth.. So I guess being used to recognizing you have to persevere through boring stuff.. - [Tina] To get to the big goal.. - Mm hmm, yeah.. - Right, super.. Okay, who has a burning question? And I'm gonna focus on students..

Tati.. - [Tati] Hi, so you said no to clean meat.. But how are you going to infiltrate if some, say the market and developing countries, with the Impossible Burger, or Impossible Chicken, or Impossible Fish knowing that in these countries the meat production is increasing and people are proud of consuming more meat, so clean meat would be the actual meat that people want, and Impossible Burger would not be the actual? - Well, I think there is an embedded assumption-- Can you repeat the question? - Oh, yeah, sorry.. The question was how do we expect to be successful, tell me if I'm, in international markets where the assumption is that real meat can only come from animals, I guess? And therefore the way that we make our meat won't be viewed as the product that they want because it doesn't come from animals.. I think that that's an embedded assumption, which I don't happen to share.. I think if you make a product that in terms of delivering the fundamental things that people want from that product, which is the pleasure of eating it, which is for a lot of people all around the world that's one of the great pleasures of life.. If you deliver that, and you can produce it at a cost that is attractive, and it delivers the nutrition, and so forth, I think in my view you're there.. Why would someone say anywhere in the world, yes, this product doesn't taste as good, yeah, it's not as good for you, yeah, it's more expensive, but it's made from animal cells, so I'm gonna buy it anyway.. I just don't buy that at all.. I think it would be just like people saying, I'm gonna wait for cars that are powered by horse muscle cells, because that's really, that's the transportation system I aspire to..

They aspire to it because that's been the only way to make it up to now.. But I think it's the product and the way you make it, I think people can easily separate those things.. - Okay, great.. Over back here.. Stand up, please.. - [Woman] I was wondering looking at creating a meat that performs also in terms of pack their molecules the same way as actual animal meat, have you thought at all about moving more towards other animal parts such as dairy that have really disturbing links to health impacts? And also, does the Impossible Burger have the same sort of negative health components like trans fats and cholesterol? - Right.. So can I just repeat it? So the question is have you considered dairy, which also has a lot of issues? And have you considered the other health issues around meat like cholesterol? - Yes and yes.. When I founded the company, our goal was not to replace meat production, it was to replace animals of food production technology.. And when we started working on a technology platform, it was relatively agnostic as to what product it would be for.. And we were, of course, actively interested in dairy as a target..

And in fact, in the first year that we existed, just based on some work, actually most of which I had done before I started the company, we actually spun off a company that's making plant-based dairy products called Kite Hill, makes cheeses, and yogurts, and stuff like that.. We spun it off because basically, although it's a great company, and the products are great, and Whole Foods, they're selling very well, you're not gonna change the world by making products that, as these were, are made using almonds as a precursor, 'cause it's just the economics don't work.. - [Tina] That's because almonds are expensive.. - Yeah, it's basically you're not gonna be able to be cost competitive, and so I felt like, but still it's successful in selling and stuff.. But anyway, that's to the side.. We cared about dairy, but we had at some point, once we felt like we had the basic know-how about how to make products in this space, and we had the toolkit, at least our starting toolkit, we had to make a choice, 'cause we can't launch 10 products at once.. And we had to choose what are we gonna launch with, and for us the ground beef was an obvious choice.. And I think actually it's interesting when you think about the dairy business, if we're successful in making a product that can outcompete ground beef from a cow in the marketplace, that actually is very disruptive to the dairy industry.. Because that's where those cows wind up.. And it's actually a non-trivial fraction of their revenue is from selling the older cows and whatever as meat..

And if we can take away that market, it's disruptive to that industry.. But we're also working on milk.. Early on, we had some actually very cool cheese prototypes.. We just decided we didn't have the bandwidth to market them.. But we'll definitely be launching dairy products when we have the bandwidth.. - Yes.. - [Woman] Thank you for your talk.. Going back to focusing on the problem, Impossible Food is a plant-based solution, Tina mentioned, lab-grown meat.. What are if there's any other solutions to this \$1.4 trillion problem? - So the question is we talk about growing meat in a lab as well as reverse engineering it.. Are there other solutions people are attempting? - Yeah, I think that's a very interesting question..

I don't know of any categorically different solutions people are attempting.. I think that there's something that is going to be part of our strategy down the road.. We started out by producing a product that very clearly was targeted at replacing a particular existing product by delivering the things that people wanted from that particular existing product.. Another strategy might've been well, if we have something that is categorically unlike that product, but that will in terms of people's eating and purchasing habits compete successfully against it, might not be exactly or even close to like meat, but nutritionally it fills the same spot, and in terms of the taste it satisfies, it's similar, that's a very real possibility, and something that we're definitely thinking about down the road.. But if we're talking about different technologies for producing food in this space, I think there are other, for example, you could produce your own ingredients entirely by fermentation, or by other means, and the question of whether you do that just comes down to which is the most scalable and economical way of doing it.. And because plants are very efficient at producing biomass directly using sunlight, and air, and nutrients from the soil, it's hard to beat that in terms of the fundamental economics.. So that's why we thought, and the fact is they're loaded with a huge diversity of potential protein and small molecule tools and so forth.. So we felt like there'd be enough there, and that that was, but you know, there are other, that's a good question.. - Back in the back.. - [Student] Hi, so I actually wanna ask to the previous question..

Or, sorry, answer, give an answer to that.. So you could theoretically genetically modify plants.. You could do that at production.. Or I guess at harvest instead of at the end, which is sort of what companies like Impossible Foods and Beyond

Meat do.. - So you want plants that grow meat? - [Student] Yeah, yeah, just maybe plants more similar to meat when they grow out of the ground instead of do the process at the end.. - Do you have a question? - Yeah, I do, actually.. - Okay, good.. - [Student] So my question is so a lot of the times, you mentioned both the ethics about caring about animals in factory farming and environmental aspects of eating meat.. A lot of times those can be prioritized differently.. So for example, dairy has a very bad effect on our environment, but it's pretty negligible compared to other animal products in how it affects the number of animals that it affects..

So how do you sort of prioritize those two, between those two? - I'd say, first of all, I feel like in general, both of those things are synergistic in terms of reasons to do this.. So what you were just saying is in both cases, they're both really good reasons to do all this stuff that we're doing, but the effect of them and the decision is different for different products.. And I would say that by and large, we're focusing on environmental impact as the key metric.. And even if you're just thinking about it from an animal welfare standpoint, basically, in terms of the destructive impact on animals on planet Earth, the destruction of habitats, and on the numbers, is a huge factor there.. So even if you're just saying let's just focus on minimizing the environmental impact, you're accomplishing a lot there.. Anyway, so you're just asking how do we take those considerations into account in priorities.. I'd say most of the time, they're not in competition, and to the extent they ever are, we'll probably lean toward the environmental impact side.. - So let me ask another question here.. - Yeah.. - So we had a program recently that was really mind-blowing to me..

It was a workshop that we did on entrepreneurship in the food industry.. And it was just amazing to think about how every type of technology touches the food industry, and there's so much room for innovation.. What are other areas of the food industry that you are most excited about seeing really big innovations? - Oh, man.. Well, I would say in terms of just from a brainstorming perspective and what the possibilities are, I think that the foods that we currently have, if you think about the kind of high-dimensional space of possibilities, and all the ways foods can be different in flavor, and texture, and all that sort of stuff, the foods we have right now are just tiny, tiny few points in that space.. And there's a huge possibility, I think, for exploring it and making entirely new foods.. So that's very interesting from a just brainstorming and theoretical standpoint.. From mission standpoint, there's a huge potential for innovation in the way we produce the raw materials for food.. So for example, one of the things that we're spending some effort on is premised on the idea that the major protein for human nutrition is going to be a protein that right now is a negligible fraction of the human diet, and is not even considered when people think about nutrition.. It's a protein called rubisco.. It's the most abundant protein on Earth..

It's the 40-ish percent of the total protein content of any leaf.. And that's part of why it's super abundant.. Unbelievably great nutritional properties, great functional properties, and so forth.. The problem is that its concentration, like there's protein in spinach and most of that is rubisco, and so plants have non-trivial amount of protein.. But in order to get enough of it in your diet, you'd have to eat ridiculous amounts of cellulose, which your body's not adapted to digesting.. So that's why we don't do it.. But if you say, well actually, we don't have to eat these plants in the native form.. If they've got a valuable ingredient, we can figure out how to isolate it, and scale it, and so forth.. And the reason why this is so interesting is that there are ways if you could economically scale the process for isolating it in a functional and food safe form, you could produce all the protein that the world needs in 2050 with a couple of percent of Earth's land area just growing alfalfa, and isolating rubisco from the leaves, which is actually an idea that we're actively pursuing.. And another even wilder idea, which nobody at the company takes seriously, but someday I think is maybe feasible, but it is a long shot, is that 45% of the photosynthetic productivity on Earth is phytoplankton..

And unlike terrestrial plants, they're life cycles are really, really fast like a couple of days.. So if you harvest a billion phytoplankton, they restore their numbers in a few days.. No irrigation, no fertilizer, no pesticides.. And less than a percent of their productivity would meet all human calorie and protein requirements.. Now nobody wants to eat plankton, per se.. - Unless you're a whale.. (laughs) - Yeah.. But it works for whales.. And that's actually the interesting thing is that people don't think of plants very seriously as a protein source, but for most living organisms on Earth, they are the entire source of protein.. Most of the protein and the diet of animals categorically on Earth comes directly from plants, and a large fraction there from phytoplankton..

Anyway, point is, if you have a way of isolating out the valuable nutrients from those things, and using them to make foods that deliver the pleasures that people want, okay, that's a whole new game.. It's technically very trivial, very non-trivial to figure out a way to harvest these things economically, and sustainably, and so forth.. But to me, it's like a very valuable thought experiment, and something that years from now when we have the resources, I want to pursue.. And I just will say one thing.. People often say, well, isn't that kind of very processed to isolate ingredients from phytoplankton and turn them into meat, and so forth? But I'll just say that everything in the food system, basically, the whole history of food is figuring out what parts of what plants and animals are delicious, and nutritious, and good to eat.. And instead of just flopping them on the plate, figuring out ways of preparing them and combining them that make something that's more than the sum of the parts, that's the whole history of food.. And that's what we're talking about doing.. It's definitely not at all deviant in that sense.. - Okay.. Where now? Over here..

- [Man] I have a question regarding the urban versus rural divide, and they exist with this product.. Particularly since the launch of Impossible Burger has been centered in very urban, very liberal ideologically centered areas, has there been any perception testing, or any sort of testing done by Impossible, and in terms of this particular meat, probably not necessarily by

cultured meat 'cause that has certainly wildly different viewpoints? - I would say we haven't systematically looked at urban versus rural.. We've sort of unsystematically got some data on it that I would say is encouraging in a lot of ways.. First of all, I would say that we have data, compelling data that basically says what matters about, just say meat, what matters about meat is the sensory pleasures, the pleasure you get from eating it, the craveability, the nutrition, and the cost.. That's what people are focusing on.. And for most Americans, and we didn't focus heavily on rural, but in the sampling it was broadly geographic across the US, the large majority love their meat not because it's made from animals, but in spite of the fact that it's made from animals, and would actually prefer and pay a premium for an identical product just because it's made from plants instead of animals.. And that's across the country, and by a large margin.. Which isn't to say that that's uniformly true.. But my guess is that, the thought experiment is it doesn't matter where you are, if someone says, here's your choice, a product that is inferior in flavor and nutrition, and cost more, but happens to be made from animals versus a product that is better in flavor and nutrition, and less expensive, and is made from plants.. I would say the vast majority of people, no matter where they are, would make that second choice..

But we'll have to find out.. The other thing is that if the concern is that somehow this is disruptive to rural economies, which is a legitimate concern, I'll just say that we share that concern, and this is not.... We're trying to create a product, and letting consumers choose.. We're not attacking anyone here.. But we recognize that it would have that impact.. And we're actively looking at ways to integrate with the existing system and not.... I mean, completely replace animals of food technology, that's for sure, but not kick out the people who are working on it now.. - So I'm gonna ask you the last question.. So here you are in the middle of this very exciting journey, but if you flashback to when you were a student, and you were sitting in a lecture hall like this, what do you wish someone had told you? What do you wish you knew when you were 20? - Hmm.. Good question..

I mean, a lot of things, boy.. (audience laughs) - But what sort of general advice? What sort of general advice do you wish someone had given you? - To some degree it was my phenotype from the get-go, but it's definitely been something that has been reinforced repeatedly by experience.. And that would be don't waste your life on things that don't matter.. I mean, of course, there are limits set on you by the fact that you have to make a living, and you happen to live in some particular place, and whatever resources and all of that.. But don't set limits on the kinds of things that you can do.. I feel like the reason that nobody has done this before isn't because no one could've done it, it's because nobody decided that actually I'm gonna make it happen.. In other words, it's because people made the assumption that the fact that it hasn't happened means it can't be done, or something like that.. So I feel like one thing I would just say is, I don't know, don't cap your own ambition.. Do things that really matter for the world.. I feel like that's what you're gonna be proud of when you're a geezer like me..

(audience chuckles) And do things that will make the world better, if you're gonna have kids, for your kids, and grandkids.. I sort of felt that way, but when I was 20, I was kind of still in the mode of sort of, sort of sleepwalking through the kind of academic trajectory, and stuff like that.. Hadn't fully formed that.. And I feel like in a way if I had gotten started from that philosophy earlier, I would've spent more time in my career at Stanford doing what I did six years ago, which is stepping back and saying, okay, I'm just gonna completely look again, start over.. What's the most important thing I could be doing now? - Well, that is totally terrific.. And we wish you the best of luck.. Please join me in thanking Patrick.. (audience applauds)..