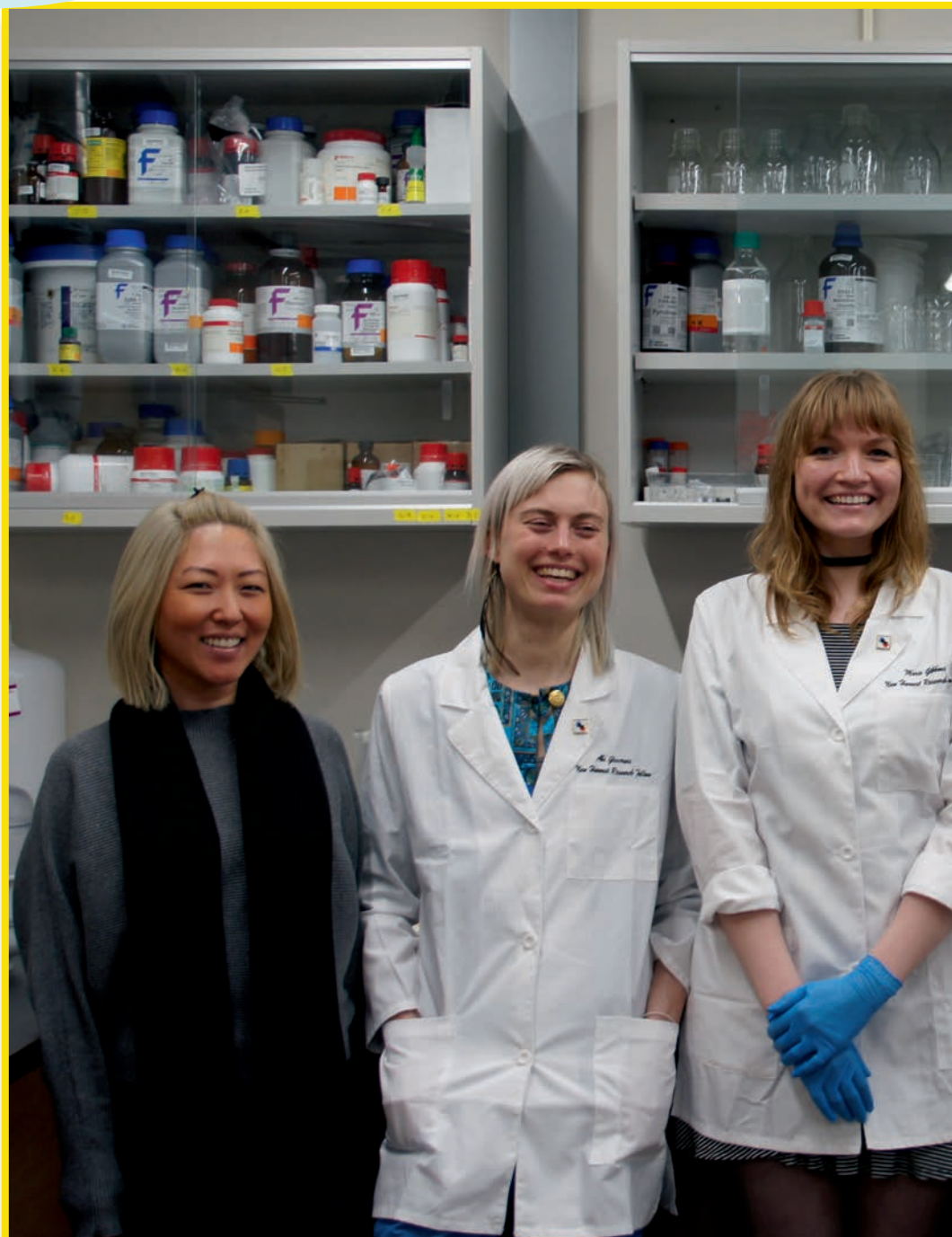
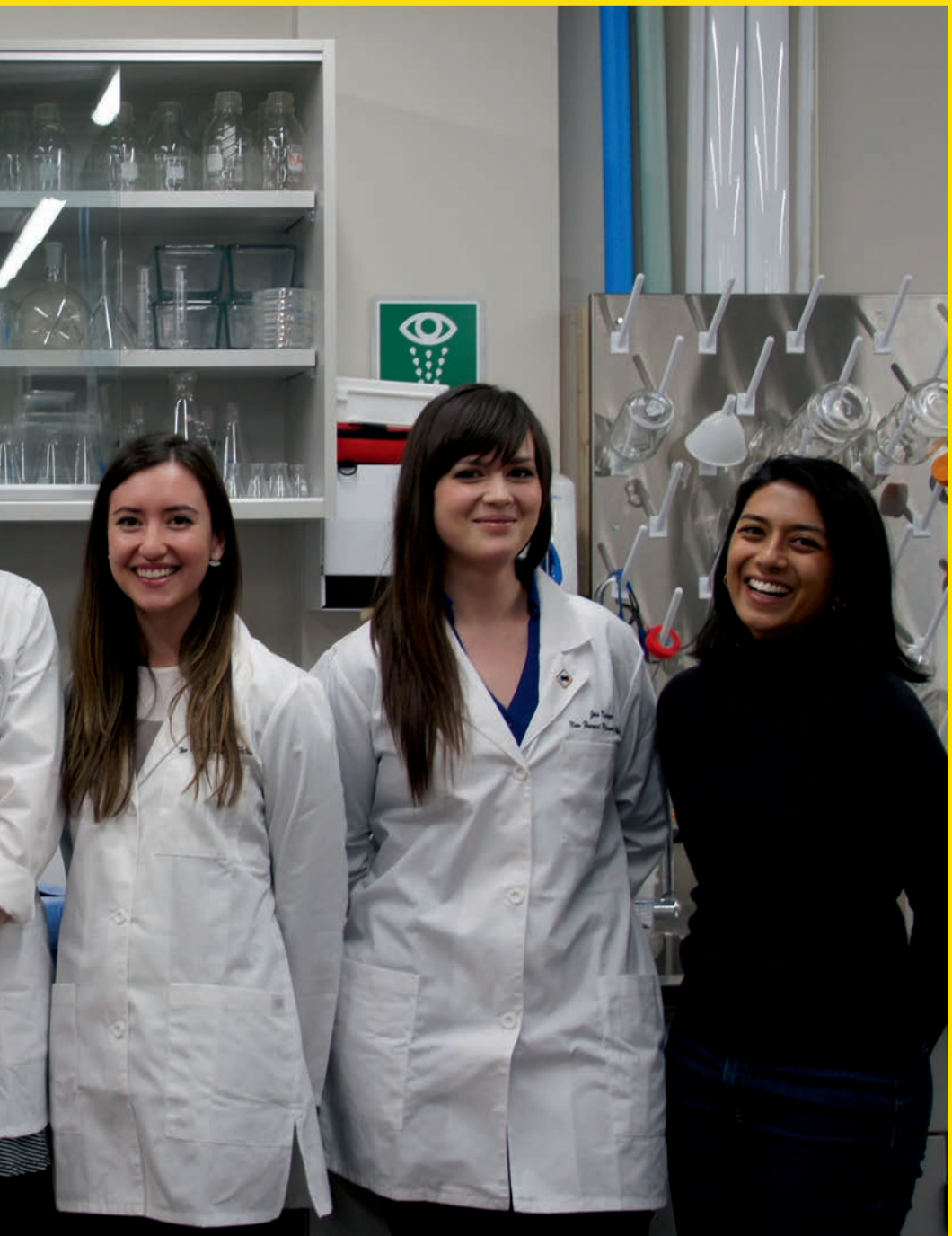




NEW HARVEST

**Annual Report & Reader
2016**





New Harvest is a registered 501(c)(3) non-profit organization in the United States of America. Contributions to New Harvest are tax-deductible to the extent permitted by U.S. law.

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Front Inside Cover

Erin Kim, Abi Glencross, Marie Gibbons, Natalie Rubio, Jess Krieger, and Isha Datar in the Pelling Lab in Ottawa, Ontario, Canada, March 2017

Back Inside Cover

The laboratory at the University of Cork, Ireland, where Perfect Day (formerly known as Muufri, and the New Harvest Dairy Project) began their work on cell cultured milk.

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Letter From Isha

I can't say how excited I am to be releasing New Harvest's inaugural annual report, albeit a dozen years after its founding. Truly there has been no better year to put down New Harvest's work on paper.

This will not be your average annual report. We wanted to go beyond the numbers, to include writings and documents that we found particularly inspiring, exciting, or generally informative about the work that we do. You will find a handful of tones, styles, and authors—just like a magazine—and I hope what comes together is a curated sense of what New Harvest is all about.

What started in 2004 as our founder Jason Matheny's unique passion project has become an ongoing global conversation, an emerging field of research, and a budding industry. There is no doubt that we, as a community, are pushing forth innovations in cell cultured meat, milk, eggs, and more, every single day.

After four years as Executive Director of New Harvest, and riding the bumps in this road, I feel the organization has settled into a groove that feels right, works well, and makes sense.

I'm proud to say that New Harvest today does not just aim to advance breakthroughs in cellular agriculture, but is making hands-on scientific progress in the laboratory. Every new data point, discovery, and breakthrough is thanks to our broad community of scientists, donors, and fans.

Thanks to your support and contributions, together we have paved the way for a new era of agriculture where we can farm cells instead of animals.



Isha

Manifesto*

There is a loud global conversation about how to feed a growing population with limited planetary resources in the face of climate change.

The consensus is that the greatest problem area is animal agriculture. Animal agriculture degrades our natural environment and is ground zero for antibiotic resistance and viral epidemics. It's also incredibly resource intensive—we use 70% of all agricultural land for farmed animals. Raising animals for food undoubtedly feeds billions of people, but it's a system that is becoming ever more precarious as extreme weather and disease events become more frequent.

In addition to the industry reaching planetary limits in terms of resource use, in my opinion, industrial animal agriculture has also reached biological limits in terms of efficiency. We can't make chickens grow any bigger any faster; we can't keep pigs in pens any smaller; we can't keep cows lactating any longer. We've optimized the use of animals as producers of animal protein, and it's still at the mercy of weather and disease.

There are many approaches to mitigating the animal agriculture problem. The most simple and obvious would be to reduce our consumption of animal products—but will we see a widespread behavioral change taking place fast enough to counter the steady growing global demand for meat, milk, and eggs? Others suggest alternatives—consuming insects, or plant-based replicas of animal products. Those are great ideas too.

But alongside these methods, we need to simultaneously look at long-term solutions that change the way we think about agriculture. We need to stretch our understanding, and the science of

*OK, so “Manifesto” sounds like a pretty grandiose and authoritative word to describe this writing but it seemed more appropriate than the other stuff we came up with. Truth be told this is some writing we pulled together, chopped, and remixed from grant applications that we wrote and I think it conveys our mission nicely. Don't be surprised if the “manifesto” in next year's report looks a little different.

agriculture, beyond farming organisms—whole plants, whole animals—and rather towards farming the most basic units of life—cells.

We want to usher in a new era of agriculture—cellular agriculture—founded on the principle of openness.

Cellular agriculture is the farming of agricultural products from cell cultures rather than whole plants or animals. This could be milk brewed by microbes, omega-3s grown in algae, or meat cultured by muscle cells, for example.

To me, this emerging science is inevitable. It only makes sense that we would move towards more controlled, contained systems for producing proteins, fats, enzymes, and other ingredients and materials for human use.

In fact, cellular agriculture is not brand new. For decades, we have been using cell cultures to produce pharmaceuticals (e.g., insulin), food enzymes, (e.g., microbial rennet for cheese making), food ingredients, (e.g., MSG), vitamins, (e.g., B12) and more (e.g., flavors, fragrances). And this doesn't count the thousands of years we've been using cell cultures for fermented foods and drinks.

What is new ground for cellular agriculture is the production of larger commodity-level products like meat, milk, and eggs. For milk and eggs, this means scaling tried-and-true techniques normally used for the products mentioned above. For meat, this means groundbreaking discovery research.

What is fascinating is that for technology with so much potential, so few people are working on it. It isn't yet funded by government grants, and large companies don't appear to be meaningfully pursuing this work.

Today the landscape is a light sprinkling of non-profits, startups, independent researchers, and Kickstarter projects.

We see this emerging field of research as an opportunity to do food science in the best way possible. For us, that means openly. We can inform the public on progress in the field as it happens. We can ensure that everyone has access to the protocols, experiments, data, and results that are being developed along the way. We can provide open forums for the public to ask questions, learn about, and even guide the science as it develops.

New Harvest Has Three Goals:

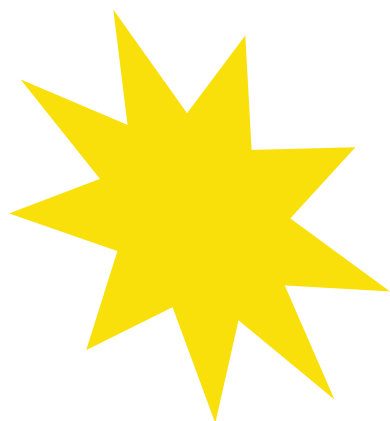
The short-term goal is creating a viable, well-supported scientific community whose members are equipped to go on to start or join cellular agriculture laboratories in industry or academia.

The medium-term goal is the creation of open, public research that asks and answers fundamental scientific questions related to cellular agriculture. This is already underway with several projects in our portfolio. We've already created and shared exciting protocols and cell cultures along the way. The first project should be complete by May 2018.

The very long-term goal is a world where the livestock industry looks more like the brewing industry. It's a vision of animal products like meat, milk, and eggs, being brewed in stainless steel tanks. Every brewery (from that of a home brewer to a massive multinational brewery) could make unique products with their own special recipes and methods, all built on the same, basic, open technology. These products would meet the needs that animal agriculture addresses today.

New Harvest is pushing these goals forward as a 501(c)(3) non-profit organization, funded to date by just under 600 people who want to see a world where the foods and materials which are sourced from animals today are instead produced via cellular agriculture. When we see cultured milk, meat, and eggs on our dining tables, in grocery stores, or on space stations one day, it will be thanks to these pioneering individuals with the foresight to envision a world that escapes the absurdities* of animal agriculture.





Mission



New Harvest's mission is to advance breakthroughs in cellular agriculture

We work towards this mission through our primary activity of funding, supporting, and coordinating academic research where animal products are made from cell cultures instead of from animals. We then report on the advancement of these projects and on the field of cellular agriculture as a whole.

Financials



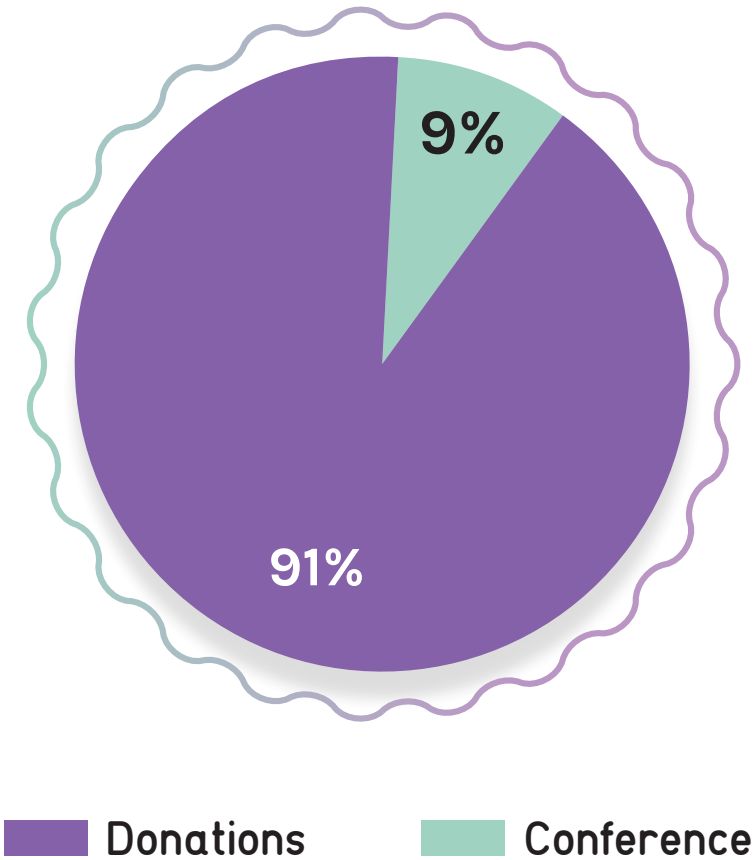
The following data comes from our unaudited 2016 financials. These are funds that have entered and exited New Harvest's accounts*

*Huge shout-out to our incredibly knowledgeable, committed (and hilarious) treasurer Dan Phillips for making our financials approachable and dare I say it: fun.

Income

In 2016, New Harvest's primary source of income was unrestricted donations from 272 donors.

The secondary source of income was ticket sales and sponsorship for the New Harvest 2016 conference.



Expenses

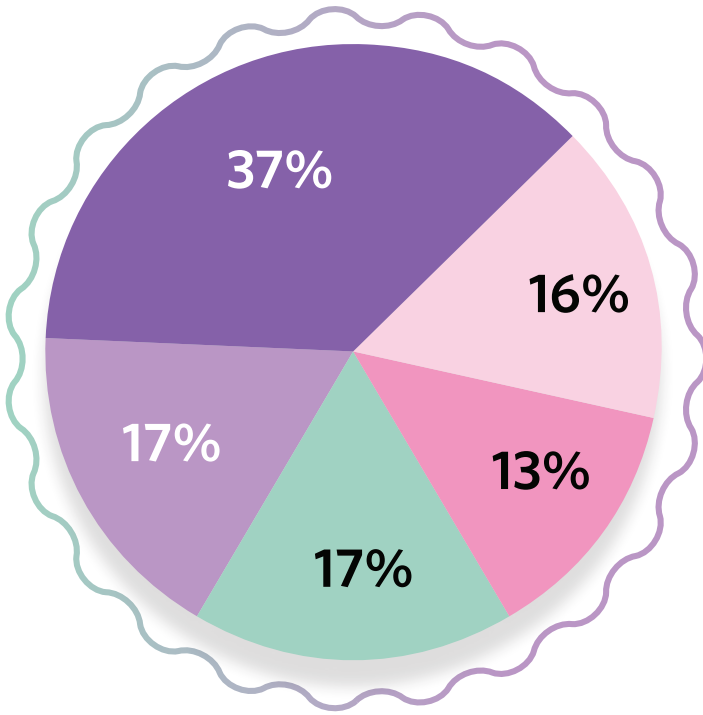
We categorized our expenses into 5 categories for 2016.

1. Administrative expenses are those incurred by the general operations of New Harvest as an organization.
2. Fundraising expenses are those incurred by any fundraising activity that New Harvest undertook throughout the year.

The remaining three categories are Program categories.

3. Research is New Harvest's main ongoing program. Expenses in this category include all grants given directly to funding academic research, plus the staffing required to manage our research effort. In 2016, \$137,624 was given as grants for research, representing 67% of the research program expenses in 2016.
4. Communications is New Harvest's second ongoing program. Expenses in this category include our media and social media effort, led by Communications Director Erin Kim, as well as any expenses incurred from giving keynotes, lectures, and panel presentations to spread the word about cellular agriculture.
5. The New Harvest Conference is our annual event to show-case cellular agriculture. Expenses in this category cover all the logistics required to put on the inaugural 2016 event.

With a team of three full-time staff, two interns in 2016, every team member found themselves working across multiple expense categories. As a result, payroll for everyone has been broken up by time commitment into the above five categories.



Administration

In 2016, New Harvest's core team consisted of three full-time staff: Isha, Erin, and Gilonne; and three interns: Daan, Meera, and Mike. The realization that New Harvest's staff is so small is often met with surprise. We think it's a great sign that New Harvest appears to be a much larger operation, with a much larger budget, than it is.

In reality, New Harvest's operation is bigger than its staff—our Research Fellows Abi, Jess, Natalie, and Marie are at the bench pushing forward the science; a roster of scientific advisors are reviewing, revising, and elevating our research strategy and proposals; our board members Jason, Scott, and Karien are guiding and governing the direction of the organization; our Treasurer Dan is diligently monitoring our financial health; and a community of volunteers are generously offering their talents in terms of conference production (thank you Morgan!), legal services, content-writing, financial planning, and much more.

We believe that a staff size that is proportionate to the needs of our research fellows is the most sustainable model for New Harvest. The field of cellular agriculture is growing but fragile. To us, every full-time dedicated career in cellular agriculture means growth in the field. We see research as the driving force behind advancements in cultured meat, and therefore we prioritize the full-time employment of dedicated cellular agriculture scientists. We build out New Harvest's staff accordingly as a support system for our growing cohort of research fellows.

A smaller staff demands that each staff member must be able to learn and do a little bit of anything and everything, but it also offers organizational flexibility and agility, and instills New Harvest with a genuine culture and brand identity that goes deeper than what can be conjured up in a boardroom.

By the end of 2016, New Harvest pared down to Isha, our Executive Director and Erin, our Communications Director. We closed the Development Director role that was previously filled by Gilonne to focus on developing our Research Program.

Goals for 2017

In 2017, New Harvest will bring on its first Research Director, Kate Krueger. Kate's role will primarily be to function as a communal, cellular agriculture-focused supervisor for our Research Fellows.

We also aim to formalize and build out our scientific advisory board. Our work with advisors has largely been ad hoc and we would like to highlight and elevate the scientists who have been offering their support, and to foster further connections and collaborations between them.



Erin Kim, Morgan Catalina, Gilonne d'Origny, Isha Datar, Meera Zassenhaus, and Daan Luining at New Harvest 2016

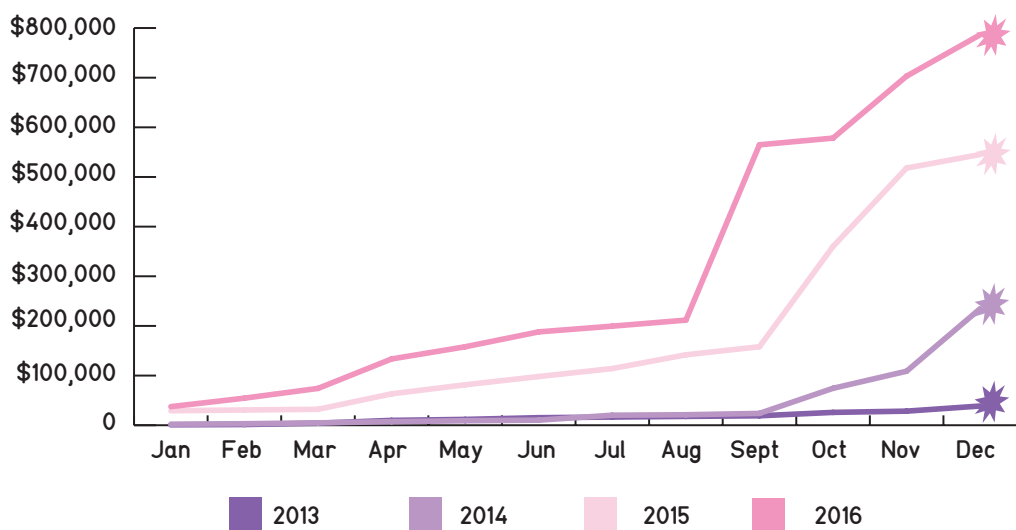
Fundraising

We include donations, conference ticket sales, sponsorship, or other income as funds raised. In 2016, we raised (on paper—we'll explain in a minute) a total of \$545,282. This is the amount of funds that entered New Harvest's bank account in 2016.

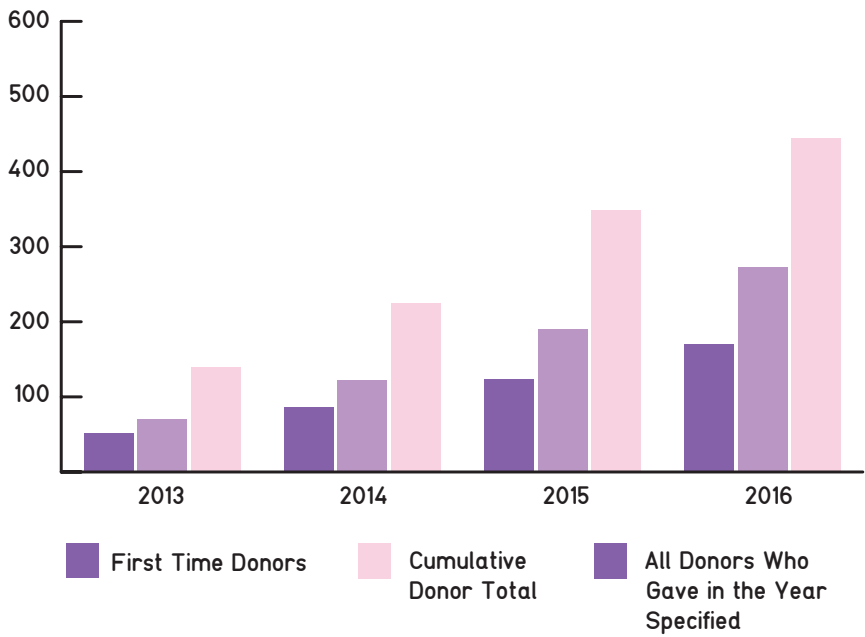
Beyond our bank account, we raised an additional \$275,000 in committed funds in 2016. This was a “non-liquid” (and therefore not sitting in our checking account) funding commitment from the Shuttleworth Foundation. Because of how the commitment is structured, we pitch for specific funds from the foundation on an as needed basis.

To put New Harvest's growth in perspective, here is what our fundraising, in terms of dollars and donors, has looked like over the past 4 years. These are the years where New Harvest has had full-time staff.

Cumulative Funds Raised Per Month Between 2013 - 2016

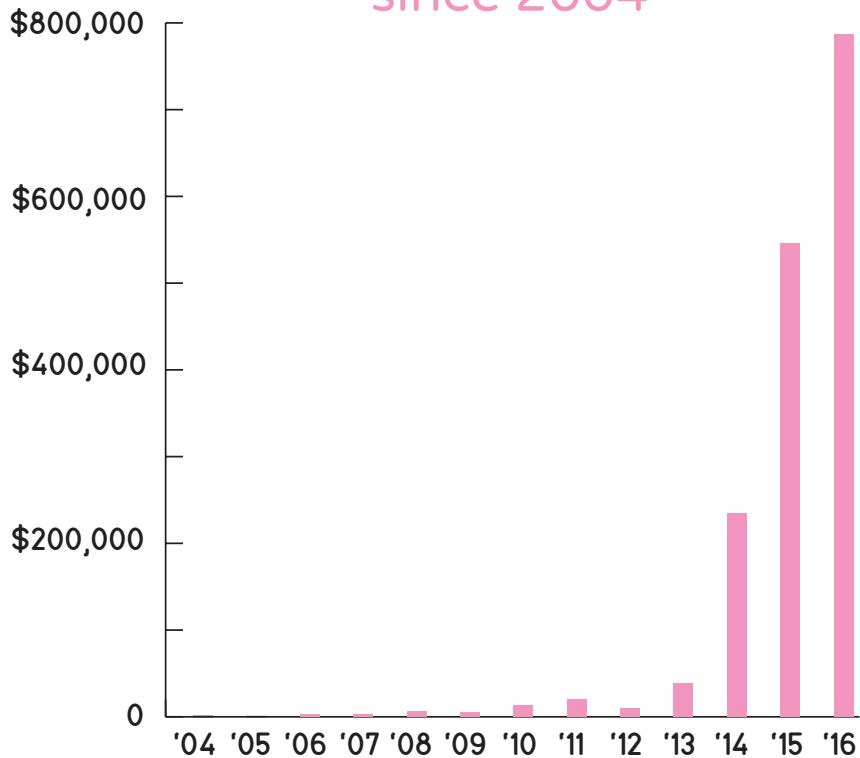


New Harvest's Donor Community



Prior to the hiring of Isha as Executive Director in 2013, New Harvest did not have any full-time staff. But funds were still raised here and there for research! Here's a snapshot of what the early days looked like for reference. We've come a long way.

Funds Raised Per Year since 2004



Goals for 2017

We would like to surpass \$1 million in funds raised in 2017. To reach that goal, we are trying a few new things.

The first is accepting restricted donations. For the first few years we only accepted unrestricted funds to give New Harvest flexibility while we determined what our core activities would be. Now that we are feeling comfortable and confident in our Research program, we are beginning to accept donations restricted for research. We have begun sending out descriptions for individual projects in our pipeline for donors to support.

We have also begun earning income from speaking engagements. By default, any income earned by New Harvest staff for speaking engagements is put towards New Harvest.

Lastly, we are beginning to pursue bigger grants and foundation support. New Harvest was built on the contributions of hundreds of individuals, and with that support we have created a story worth telling, a straightforward model worth funding, and strong results. While we know that interactions with these groups can be years long, we're ready, confident, and excited to put our work and vision in front of major funders and foundations.

Communications

So what is Communications at New Harvest anyway? Admittedly, it's a pretty broad category for us. Although I had been helping out with social media, newsletter mailings, content writing, and outreach for a couple of years prior as a volunteer, 2016 marked the first year that New Harvest had someone on board dedicated to Communications full-time. In May of last year, I added media relations, fundraising communications, and any messaging related to the conference to my formal list of responsibilities (as well as picking up many of the myriad miscellaneous duties that come along with working at a small non-profit). Near the end of the year, I faced a huge fear of mine and started to take on speaking engagements here and there as well—it's been a terrifying, but very rewarding experience.

Having been part of the cellular agriculture field since 2014, I've seen the public discourse change over the years. A lot of the tone, the players, and the content are different today than they were just a few years ago. We're no longer alone, and more people are listening. With a few years worth of content to look back on, our own message is evolving and becoming more distinct. Our voice as an organization has changed too, for the better. There's room now for us to be more authentic, as our real, "millennial" (ha), food-loving, and occasionally silly selves—in certain contexts.

We're quite selective and strategic about the media engagements we choose to accept. We prioritize coverage in science publications and food magazines, and we've found that our story and the work that we do translates much better in video stories and thoroughly researched, deep-dive style articles that approach cellular agriculture in a thoughtful and relatively grounded way.

*Believe me, I'm rolling my own eyes at myself as I say this—but it counts!

I'm also much more likely to engage with a media request if it will reach newer audiences, which, at the moment, I would say includes farmers, food producers, and "big food" (working with Taco Bell in the context of cell ag remains a dream of mine...)! I think we need to make space for each of these kinds of voices in order to have a more well rounded and nuanced public conversation around cell ag.

Much to the chagrin of most journalists, we're especially wary of making promises about how and when cellular agriculture products will reach the market. So much of what surrounds the future products and processes is unknown or purely speculative at this time—I think it makes more sense to highlight the work that needs to be done today, than to treat the future products as an inevitability.

At New Harvest, our "product" is inquiry. It's asking and answering questions about if and how cellular agriculture can replace animal products. We want people—scientists and non-scientists alike—to be aware of and able to keep up with the developments in this space as they happen, and to be equipped with the requisite knowledge to ask the right questions about this novel method of producing food and materials, even if that means critique (which can be of great value as well).

Our journey through 2016 cemented transparency and openness as core values for New Harvest across all of its activities - in how we conduct and communicate our scientific progress, and how we operate as an organization. This means not only sharing our successes but also our challenges, how we worked through them, and the lessons we learned.

In reflection on the past year, my overarching takeaway is that New Harvest's Communications has evolved towards informing the public on a deeper level about cellular agriculture, rather than simply advocating for it.

Goals for 2017

For 2017, we would like to attract and engage with new and broader audiences in the science and food communities through press, speaking engagements, and outreach.

We're looking forward to introducing fresh content and imagery generated by our research program and conference, and we're eager to move further beyond our "introductory" content (e.g., on the problems of animal agriculture) towards deeper, more nuanced conversations about what a world with cellular agriculture may look like, and the scientific challenges and opportunities that lay ahead.



erin

The New Harvest Conference

By 2015, the hunger for an accessible, informative gathering of all of the international goings on in cellular agriculture became palpable. It dawned on us that New Harvest could begin to fill that void by holding a fun, accessible, and still educational conference focused on the vast array of applications of cellular agriculture—to food, materials, and more.

After just 6 months of planning, and with the invaluable help of our producer Morgan and intern Meera, our inaugural conference was held on July 13, 2016 at the Golden Gate Club in San Francisco. The conference was attended by over 300 scientists, entrepreneurs, students, investors, philanthropists, and prospective consumers of cellular agriculture from across the U.S. and countries including Cambodia, Denmark, Israel, Ireland, Japan, The Netherlands, and the U.K. Speakers, sponsors, and exhibitors included Drs. Mark Post, Marianne Ellis, and Paul Mozdziak; Andras Forgacs of Modern Meadow; Perfect Day Foods; Clara Foods; Memphis Meats; Geltor; Forelight; Soylent; The ODIN; and Spiber x North Face. The event was covered in the press by outlets including History Now, the MIT Technology Review, Business Insider, Science magazine, Fast Company, and AgFunder.

Conference 1.0 resulted in a boost of interest in cellular agriculture from the media, the public, and industry. The response from attendees surveyed afterwards was resoundingly positive. Making the decision to hold the conference annually from then on wasn't difficult, and we decided to expand the conference to two full days to allow for even more programming and networking time.

*For a behind-the-scenes look at what it was like to run the conference from backstage, check out Erin's recap in the "Selected Writings" section on Page 171.





Goals for 2017

Based on feedback from our 2016 conference, we plan to increase the amount of scientific content, extend the conference to two days, expand our exhibition space, and create more networking opportunities for our attendees in 2017.

We'd love to pull in more fresh faces to both the audience and the speaker lineup for the 2017 edition of the New Harvest conference. Our programming will focus on giving an update on the state of cultured meat research today, followed by talks that extend our understanding of what cellular agriculture is and how it works. We've also planned for some thoughtful and friendly debates to highlight the opinions and perspectives of people who may be impacted by cellular agriculture.









Research

Our experiences in 2016 helped us establish the foundation for our Research Fellowship Program, but it wasn't without some bumps in the road.

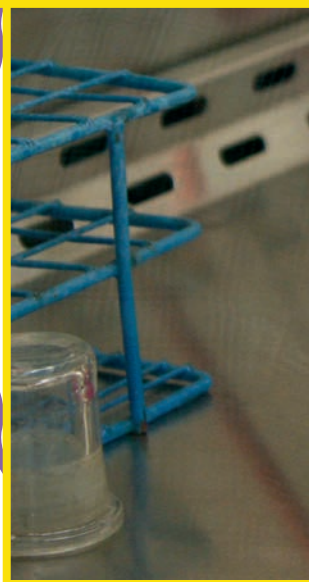
Come mid-2016 we were set on building New Harvest Labs. The idea was that if we built our own bricks and mortar laboratory, we could ensure that all the research coming out of it would be open source. It would give us enormous freedom in pushing forward openness in cellular agriculture.

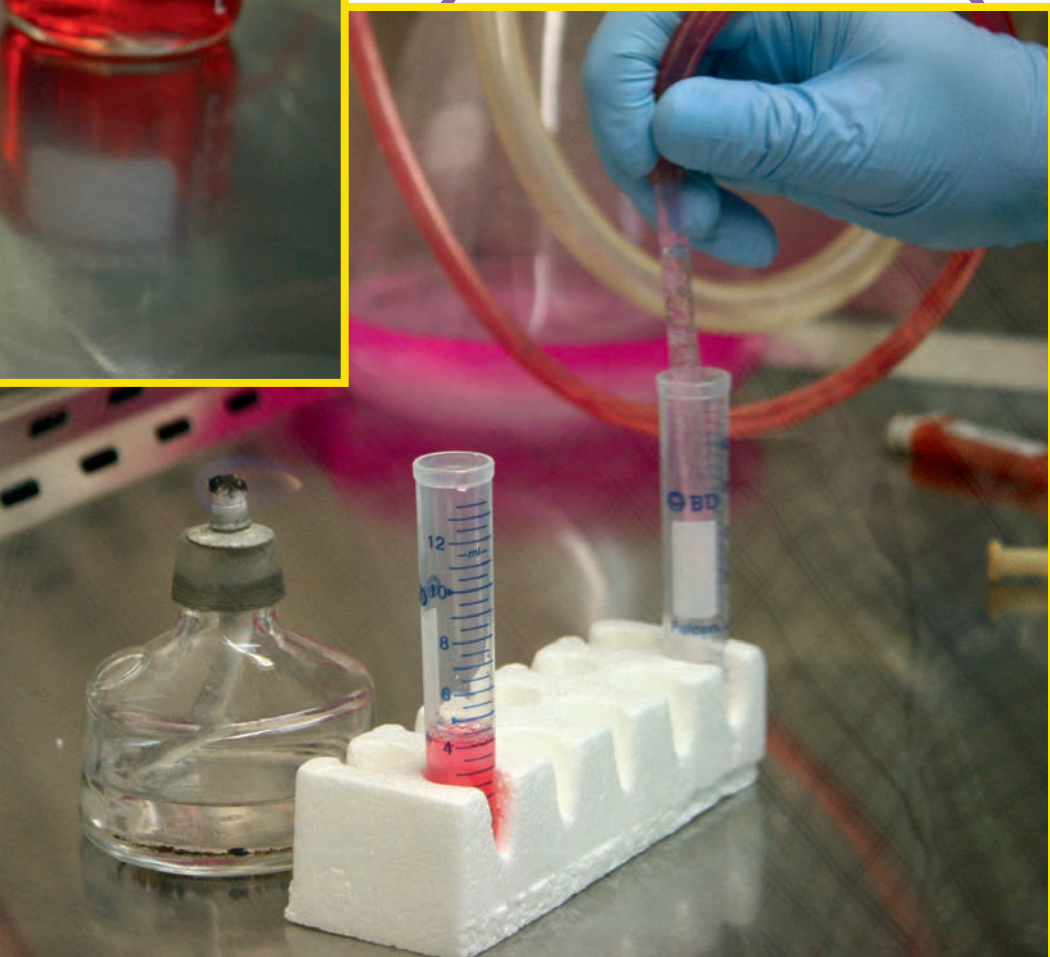
The concept itself is not flawed, and perhaps down the line we will revive it, but by fall of 2016 we decided to put New Harvest Labs indefinitely on hold. As we delved deeper into the finer details of the project and the realities of running not a mere satellite office but a fully outfitted tissue engineering wet lab, it became clear that we weren't financially or organizationally ready. It was a project that carried too much risk for an organization of our size.

With some regret, and more relief, we made the decision to put our plans for the lab on the shelf and refocused our efforts on growing and improving the Research Fellowship program.

The New Harvest Research Fellowship program is the heart of what we do.

On a rolling basis, New Harvest invites and accepts fellowship applications focused on advancing breakthroughs in cellular agriculture. These are project ideas fleshed out by the researchers and/or supervisors who will be conducting the work themselves. There aren't too many restrictions.





1. The research and results must remain as open as possible throughout the progression of the project.
2. The research must be critically neglected; that is, unlikely to be funded by any other existing funding mechanism. A project is selected after a rigorous independent review and revision process, and after meeting and getting to know the supervisor and student who will be pushing it forward in the lab.

The idea of a non-profit organization funding research fellowships is not particularly novel, but we believe the experience that we offer fellows is. We focus on support and community. In late 2016*, we observed that cellular agriculture researchers needed much more than financial support. In response, New Harvest prioritizes fostering a collaborative environment for research fellows to:

1. Seek and provide practical guidance on day-to-day protocols, procedures, and research methods.
2. Be trained in out-of-laboratory skills like science communications and public speaking.
3. Ride the ups and downs of research in an emerging field as a community.

A New Harvest Research Fellow does not only join the physical laboratory where they are conducting their research; they also join a distributed community of scientists with different areas of expertise, all working towards the same goal.

In addition to being on the front lines of the science, the New Harvest Research Fellows are ambassadors for cellular agriculture

*See “We Closed Our First Research Project” on page 137

and New Harvest's work. Fellows regularly present at speaking engagements, academic conferences, and selected media engagements as their academic schedules allow.

We focus on the program as fellow-oriented rather than project-oriented because we feel it builds resiliency. The field of cellular agriculture is growing but fragile. Our thinking is that every additional person committed full-time to cellular agriculture strengthens the field, and that the types of people the field needs most are scientists.

We invest in people who are committed to this work through thick and thin—through the ups and downs of scientific research and the funding behind it. We fund people who can catalyze growth—through seeking collaborators, attracting support, and being advocates for the importance of this research. After they complete their fellowship, they will be an expert in an area of the field, part of a growing talent pool of people ready to work in cellular agriculture-focused laboratories in academia or industry.

We chose the Fellowship Program as our core means of advancing cellular agriculture science for several reasons.

1. Scalable—While we haven't quite determined what the optimal ratio of New Harvest Staff to fellows is, it is easy to see how this program can scale, and how scaling strengthens cellular agriculture at large.

2. Stretchy and Resilient—Because we do not set a yearly quota of new Fellows, the number of Fellows can ebb and flow with available funding.

3. Flexible—Projects at the forefront of science must remain flexible – they may change as we learn more, they may pivot with new materials and techniques, and they may not work out at all. Focusing on Fellows offers us flexibility in Project design throughout the discovery pathway.

4. Catalytic—Fellows begin seeking further funding throughout their fellowship. We have not been successful with a follow-on grant so far, but we believe the chances will increase as the field grows.

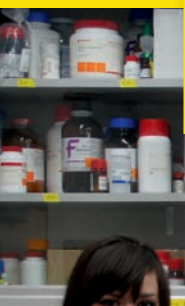
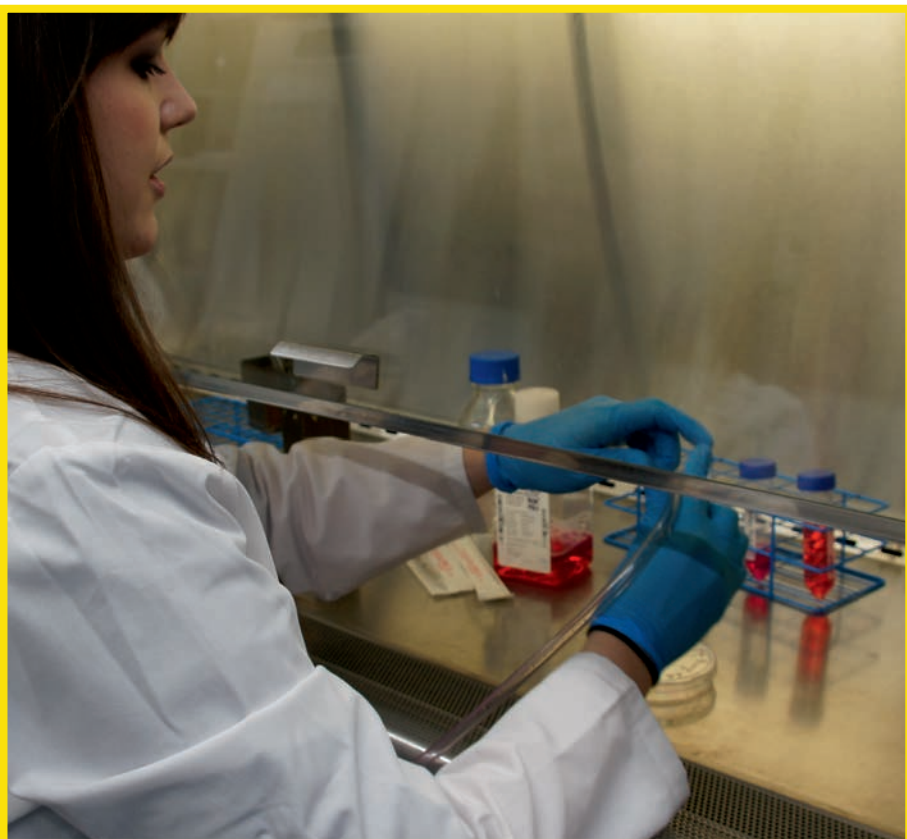
5. Community Building—Fellows build communities around themselves as they train and collaborate with undergraduates, summer students and other researchers.

Our strategy in choosing and designing projects is based on an understanding of the research gaps that exist in cellular agriculture, particularly for cultured meat production today, combined with the skills and expertise of the fellows we fund and their supervisors.* Broadly speaking, we are focusing on developing the starter cultures of cultured meat—the beef, pork, chicken, turkey, and other cell cultures that scientists and manufacturers will need to source to begin cultured meat research and production. (At present, obtaining these cells requires a visit to the slaughterhouse, or expensively contracting someone else to visit the slaughterhouse for you.) The idea is that by making these initial cell cultures openly accessible, we will significantly lower the barrier to entry for those wanting to pursue work in cultured meat.

Once the cell cultures are established, we are better positioned to investigate scaffolds, bioreactors and media. Some of these projects can be investigated in tandem, but others must be sequential.

** See “A Primer On Cultured Meat Production” on Page 125 for a generalized overview.





Despite our focused but flexible strategy, we continue to keep our project application guidelines open-ended to ensure that we can attract all kinds of new cellular agriculture research ideas. We are happy to support projects that fit within our portfolio, and happy to find support for projects with promise that don't quite align with our goals.



Goals for 2017

We hope to strengthen our Fellowship program in 2017 and beyond with the addition of Kate, our incoming Research Director. Kate begins in July and she will help formalize and improve certain new aspects of the program with feedback from our existing fellows. She will also be building out our scientific advisory board.

We hope to bring on four additional Research Fellows in 2017. These fellows will be working in cell biology, scaffold design, and bioreactor design.

We are eager to begin research on animal-free growth media for cell cultures. We hope to take on these projects once the appropriate cell cultures—for beef, pork, chicken, turkey, etc.—have first been established; serum-free media are usually specifically designed for specific cell types and species.

Project Catalogue



This is an overview of the projects funded/supported by New Harvest over the years, in chronological order. We've also included some 2017 projects from our pipeline which haven't begun yet

Environmental Impacts of Cultured Meat Production

Project Dates:

Jan 2009 – June 2011

Project Lead:

Hanna Tuomisto

Funds from New Harvest:

\$10,000

Project Location:

Oxford, England

In 2008, New Harvest funded the first environmental impact assessment of cultured meat. The study, conducted at Oxford University by Hanna Tuomisto, was a life-cycle assessment* that compared cultured meat to conventional beef, sheep, pork, and poultry production across a variety of parameters: energy use, greenhouse gas emissions, land use, and water use.

The paper predicted that, based on current published figures and research, complete replacement of conventional meat with cultured meat in the EU would result in an incredible 78-98% reduction in greenhouse gas emissions, 99% reduction in land use and 82-96% reduction in water use, and 45% reduction in energy use.

On June 17, 2011**, the paper was published in the journal *Environmental Science & Technology*.

The authors acknowledge that as the technology for producing cultured meat in large-scale production plants is currently not well defined, there are many uncertainties about the data of the environmental impacts of cultured meat production presented in this paper. Hanna and others are working towards more accurate speculative life cycle assessments.

* A life-cycle assessment is a technique to assess environmental impacts associated with all the stages of a product's life from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling.

**Environmental Impacts of Cultured Meat Production. Hanna L. Tuomisto and M. Joost Teixeira de Mattos. *Environmental Science & Technology* 2011 45 (14), 6117-6123

This becomes easier as cultured meat research advances and more is known about the processes involved.

Hanna's study has sparked further investigation into the impacts of cultured meat production, independent of New Harvest support. She published further research in 2012 and 2014, and a separate group of American researchers published a new life cycle assessment on cultured meat in 2015*. We're excited to see the environmental study of cellular agriculture grow alongside advancements in the field.



* Anticipatory Life Cycle Analysis of In Vitro Biomass Cultivation for Cultured Meat Production in the United States. Carolyn S. Mattick, Amy E. Landis, Braden R. Allenby, and Nicholas J. Genovese Environmental Science & Technology 2015 49 (19), 11941-11949

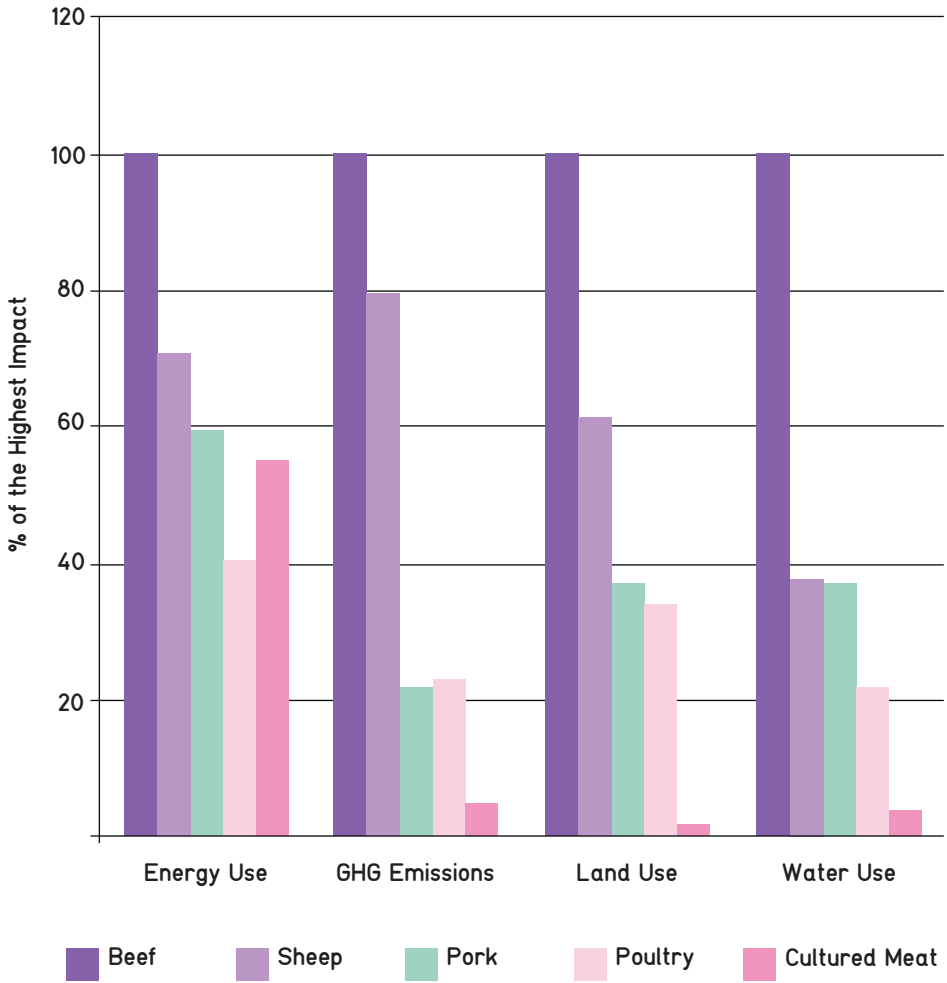


Figure 1 Comparison of primary energy input, greenhouse gas (GHG) emissions, land use, and water use of cultured meat production with conventionally produced European beef, sheep, pork and poultry per 1000 kg edible meat as a percent of the impacts of the product with the highest impact in each impact category.

New Harvest Dairy Project

Project Dates:

April 2014 - Aug 2014

Project Leads:

Ryan Pandya &
Perumal Ganhi

Funds from New Harvest:

0

Project Location:

Oxford, England

In early 2014, Isha brought together Ryan Pandya and Perumal Gandhi, two members of the New Harvest community, to begin the New Harvest Dairy project.

Isha was feeling underwhelmed at how little wet-lab research New Harvest could fund due to budgetary constraints. In April 2014, a friend had told her about the new Synbio Axlr8r (now called Rebel Bio) in Ireland, which was keen to fund early stage synthetic biology companies.

The idea of producing milk in cell culture was first presented to Isha by Ryan in 2013, then independently presented again, by Perumal in 2014. Ryan had already begun developing a research plan for producing cell cultured milk by the time Isha approached him in mid-April. Isha emailed Ryan and Perumal and asked them if they wanted to start a company in a foreign country over the summer. Miraculously, they both said yes, and were eager to work together, despite never meeting one another.

After five days of scrambling to put together an application, the New Harvest Dairy Project submitted their proposal and waited. Within days, the project was approved. The team met altogether in person for the first time on May 20, 2014.

The fundamental concept behind the New Harvest Dairy Project was to produce bioidentical milk proteins in recombinant microorganisms rather than in lactating milking cows. The concept of producing proteins in cell culture is not novel—it is already done to produce various food ingredients, enzymes, and vitamins. What was novel about the New Harvest Dairy Project was producing milk proteins. Milk proteins require much larger scale production, and milk proteins themselves had not been produced or isolated from microorganisms before.

The project was a departure from the focus on cultured meat, and was instrumental in broadening the idea that cell culture could be used to create several other types of animal products.

Journalists began inquiring about the New Harvest Dairy Project after reading about it in the New Harvest newsletter. Ryan and Perumal were offered the chance to write their own piece about their work in the "Big Ideas" section of New Scientist.

After several months of creating prototypes in the lab, consulting Irish dairy expertise, and perfecting their pitch, Ryan and Perumal were getting ready to exit the accelerator and take their project into the real world. They decided on the company name "Muufri."

Investors began approaching the team after reading the New Scientist article. In August of 2014, Ryan, Perumal, and Isha found themselves in Hong Kong, getting ready to receive their next round of funding. It was in the Horizons Ventures board room, with her pen hovering above the term sheet, that Isha decided to step down as founder, and to hand over all her equity to New Harvest. If this company succeeds in putting cultured milk on the market, New Harvest will have an endowment to further fund early stage, public research.

Today, Muufri is called Perfect Day Foods and is completely independent of New Harvest. The company is based in South San Francisco, where the team has grown to 15 full time staff. We're always excited to meet new team members and taste their latest prototypes, and we're honored to be part of their founding story.

Learn more about Perfect Day's exciting work at
www.perfectdayfoods.com





New Harvest Egg Project

(Now Called Clara Foods)

Project Dates:

April 2014 - March 2016

Project Leads:

Arturo Elizondo &
David Anchel

Funds from New Harvest:

0

Project Location:

San Francisco, California

The New Harvest Egg Project was born out of the same conditions as the New Harvest Dairy Project. With too little funding to provide ourselves, New Harvest had to search for external opportunities to fund cellular agriculture science. In this instance, the opportunity came from IndieBio SF, a biotechnology-focused accelerator backed by SOS Ventures. David Anchel and Arturo Elizondo were two New Harvest community members who started this company in late 2014.

David is a PhD cell biologist from Toronto who first started thinking about animal-free meat in 2000, when discussing “meat trees” with his father on a camping trip. An animal lover, he had long believed that cultured meat could become a “humane” source of meat. He credits cultured meat as the reason why he got into biology.

Arturo is a Harvard grad who has worked in all kinds of incredible places—the U.S. Supreme Court, the White House during Obama’s first term, and the USDA, to name a few. When I met him, he had just turned down a big deal investment banking opportunity to get serious about sustainable animal-free foods.

Isha was heading out to San Francisco in November 2014, and decided to invite David Anchel to shadow her while there. He had just finished up his PhD defense and was eager to move onto something related to removing animals from animal agriculture. Isha thought the opportunity to visit with the New Harvest Community on the west coast would be good inspiration. It turns out it was! Just days into his visit, David told her that he had been “staying up all night” researching how to make egg proteins in culture. Inspired by visiting Hampton Creek, Perfect Day, and a food accelerator event, he thought it was an obvious, neglected project.

It was at the food accelerator event that Isha and David met Arturo. Arturo had just written a paper that suggested that China should invest in cultured meat research to meet future sustainability goals. It was here that he shared that he moved to San Francisco to become a sustainable food entrepreneur.

Just days after returning from the Bay Area, Isha called David and Arturo, asking them if they wanted to make cell cultured egg proteins together. David had already prepared a scientific plan, and Arturo was ready to grow into the role of CEO. They didn’t have to mull over it too long before deciding to be co-founders of the New Harvest Egg Project.

The basis of the New Harvest Egg Project was no different than most potential cellular agriculture products. A huge percentage of eggs from battery cage raised hens go into processed foods such as sauces and baked goods. Aside from the animal welfare issues associated with raising animals this way, this type of animal husbandry is prone to public health issues. In fact, it was amidst Clara Foods’ early days that the 2015 H5N2 avian flu broke out, costing 43 million birds’ lives, causing the price of eggs to increase 120%.

In addition, the demand for egg whites regularly outpaces the demand for egg yolks. By culturing egg white in controlled environments, it would be possible to address some of these issues. The egg white protein mixture could even be tailored for specific functionality—for instance to make a fluffier meringue or a thicker custard.

After painstakingly putting together their application and submitting it, David and Arturo were accepted into the IndieBio SF accelerator program. Within days, they were renamed Clara Foods—a nod to Arturo’s Mexican roots and David’s beloved late dog—and were hard at work in the lab, building their first prototypes. Months after they got started, Clara Foods raised \$1.75 million to take their vision forward.

Today, Clara Foods is completely independent of New Harvest. The company is based in South San Francisco, where the team has grown to 22 staff. It’s always a thrill to see Clara’s progress, and we wish them the absolute best in their quest to make the world’s first cell cultured egg proteins.

Learn more about Clara Foods’ exciting work at:
www.clarafoods.com



Serum- & Antibiotic-Free Media For Bovine Myoblast Culture

Project Dates:

Jan 2015 - June 2015

Project Lead:

Mark Post

Funds from New Harvest:

\$50,000

Project Location:

Maastricht,
Netherlands, Maastricht
University

In August 2013, the first cell-cultured hamburger was cooked and tasted on live television in London, England. Professor Mark Post and his team created this burger at the University of Maastricht using, for the most part, routine tissue culture protocols. After completing the prototype, Mark had several avenues he wanted to pursue to improve upon the cultured meat production process.

One of the challenges of routine tissue culture is the dependence on animal sera, specifically fetal bovine serum, to feed growing cells. A second challenge is the dependence of tissue culture on antibiotics to keep culture flasks free of contamination. An ideal cultured meat production system would not be dependent on either of these components.

In early 2015, New Harvest provided Mark's laboratory with \$50,000 in funding to conduct research aimed at animal-free, antibiotic-free media for growing cultured meat.

About 400 serum-free and antibiotic-free conditions were tested for culturing bovine myoblasts* Researchers found some formulations that sustained myoblast growth, although their growth was typically delayed by one or more days.

* Myoblasts are muscle cell precursors

They also found that replacing only 75% of the medium was compatible with cell growth, and that in the absence of antibiotics, growth performance was enhanced without an increased incidence of infections. Mark's work continues to look towards optimizing the growth conditions for promising formulations and to determine if slower growth in the absence of serum is a problem or an advantage (better cell differentiation* occurs with slower growth).

Mark's research team has submitted a manuscript with these results to the journal *Cytotechnology*.



* Differentiation is the process of one cell type changing into another. In this case, muscle precursor cells (myoblasts) becoming muscle cells (myocytes).

Creation of In Vitro 3D Vascularized Skeletal Muscle Tissue For the Production of Cultured Meat

Project Dates:

Nov 2015 - May 2017

Supervisors:

Dr. Lucy Di-Silvio,
Dr. Mark Post

Funds from New Harvest:

£44,299.13

Project Location:

London, England
King's College London

Research Fellow:

Abi Glencross

Abi Glencross is New Harvest's first Research Fellow. Prior to receiving her grant from New Harvest, Abi had studied chemical engineering with Dr. Marianne Ellis (Marianne applies chemical engineering principles to the design of bioreactors for large scale tissue culture).

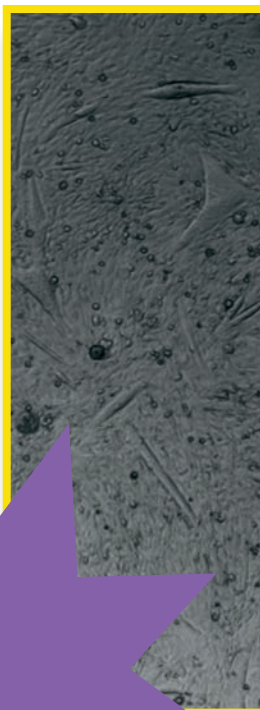
In 2015, Abi put together a PhD proposal with Drs. Mark Post and Lucy Di-Silvio for a project focused on creating cultured meat. Her project was specifically about creating three dimensional vascularized muscle tissue—in other words, thick cuts of meat like a steak or chicken breast rather than a “ground meat” type of product like hamburger. In order to do this, she would have to investigate scaffolding materials for muscle cells to grow onto, and methods for growing vessels into the three-dimensional tissue. This way, nutrients and oxygen could penetrate deeply into the growing muscle tissue.

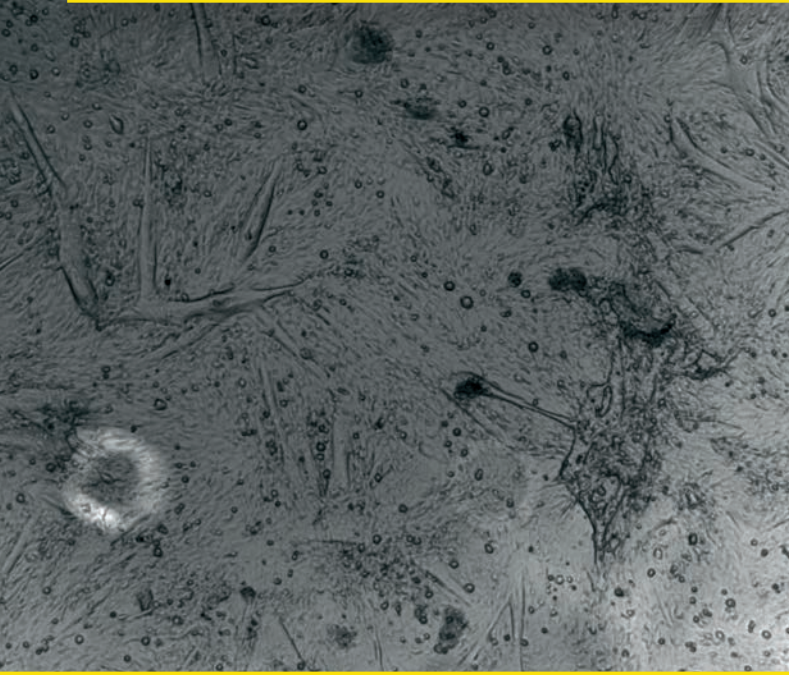
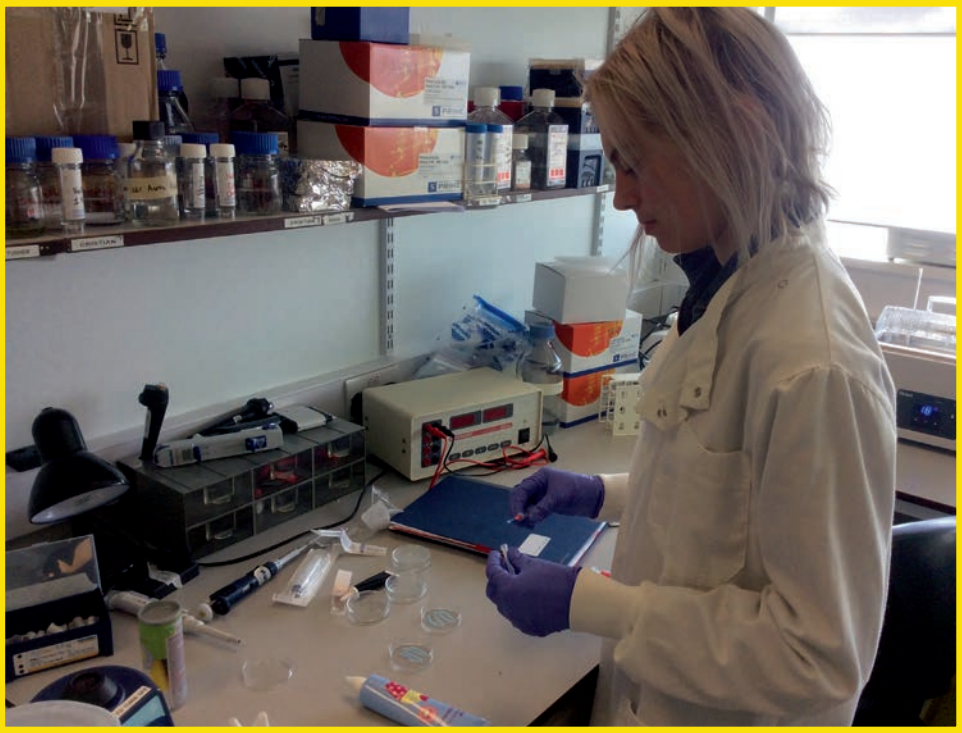
As the first New Harvest Research Fellow, Abi's first lessons in cellular agriculture had to do with the basics of animal cell culture, such as growing cells, changing their flasks, seeding them onto scaffold materials, quantifying RNA, and techniques to prevent cell death and contamination. She experimented with scaffold materials

like Quorn, tofu, mushrooms, and sugar, along with her work on perfusion of collagen. In addition to her work in the laboratory, Abi became a vocal advocate for cultured meat research. She has given numerous public lectures and media interviews on the topic throughout her fellowship.

When this work was first funded, New Harvest's research program was called the Seed Research Program. It had the same aims as the current Fellowship program, but with more focus on the project rather than the person conducting it.

Due to several difficulties, on May 1, 2017 New Harvest discontinued this project. It was a difficult, but mutual decision which we learned a lot from. You can read about how and why we came to the decision to close Abi's research project in the [Selected Writings](#) section on page 137.





In Vitro Avian Myoblast Suspension for Mass Scale Production and Consumption

Project Dates:

April 2016 - May 2018

Supervisor:

Dr. Paul Mozdziak

Funds from New Harvest:

\$118,800

Project Location:

Raleigh, North Carolina,
USA—North Carolina
State University

Research Fellow:

Marie Gibbons

Marie first got in touch with Isha as an applicant for the New Harvest Cultured Tissue Fellowship at Tufts University. After an initial call, Marie told Isha about Dr. Mozdziak, (aka “Dr. Paul”... it’s a Southern thing, he says) and how he had been interested in cultured meat research as well. He is an expert in avian muscle cell culture. Isha suggested a chat, because working on a directed project with Dr. Paul sounded like it could be very impactful.

Dr. Paul shared in our first meetings that he has believed in cultured meat for decades. In fact, he had been keeping a vial of turkey cells since 1993 in the -80°C freezer with the hope to one day work on cultured meat research.

We decided it was best for Dr. Paul and Marie to design a project together. We at New Harvest felt that the most important work was focusing on establishing cell cultures for agricultural animals so that they could be easily shared amongst researchers and entrepreneurs to advance cellular agriculture. So far, it was very difficult to obtain “starter cultures” for cultured meat—it often warranted a visit to the slaughterhouse or an expensive order from a contract research organization.

The goal of Marie's research is to first create a starter culture of avian cells then second to adapt them to grow without a scaffold. If it is possible to grow cells in liquid suspension, it becomes easier to grow large quantities of cells very quickly. The challenge is in creating cells that can grow in suspension and still mature into muscle fibers. Dr. Paul believes that avian cells have promise for cultured meat production. He believes that white meat's low anaerobic activity, low fat content, and cellular plasticity make it an ideal starting point for cultured meat research.

Since receiving a grant from New Harvest in April 2016, Marie Gibbons has been establishing the turkey cell culture. Marie began by obtaining a very small muscle biopsy, about half the size of a grain of rice. This procedure can be performed by a veterinarian using gas anesthesia and pain medication, without causing any harm to the animal. From there, she extracted the muscle cells from the tissue using enzymes and helped the cells adjust to life outside of the body by providing them with similar surroundings and nutrients. Marie maintained them in cell culture flasks over several months and began building a cell bank for other researchers to easily access.

After establishing a cell bank consisting of around 375 million cells, Marie moved on to the next phase of her research—suspension culture. In the body, muscle cells like to be attached to something, such as connective tissue or other muscle cells. However, the ability to grow muscle cells in suspension, rather than on a two-dimensional surface, would allow for the in vitro muscle production process to be much more scalable and efficient. She is currently selecting for cells that are slow to attach, adjusting conditions within the bioreactor, and adding specific transcription factors to the media to keep cells in a more “stem cell-like” state while inhibiting

attachment. These cells can survive in suspension and, when placed in flasks and given attachment-promoting factors, are able to fuse into muscle fiber precursors called myotubes.

Once Marie has optimized her suspension culture conditions and attachment rates, it will be time to move on to serum-free media formulations, plant-based scaffolding trials, and large-scale protocol applications for a variety of other meats such as pork, beef, and fish. If Marie's research is successful, scientists from all over the world will soon have access to protocols and cells that can be used for animal-free large scale production, bringing us ever closer to meat without animals.



New Harvest Cultured Tissue Fellowship

Project Dates:

June 2016 - June 2019

Supervisor:

Dr. David Kaplan

Funds from New Harvest:

\$167,067.24

Project Location:

Boston, Massachusetts,
USA—Tufts University

Research Fellow:

Natalie Rubio

New Harvest was connected to Dr. David Kaplan by Ryan Pandya of the New Harvest Dairy Project, now Perfect Day Foods. Ryan was a former student of Dr. Kaplan's who did a research project on cultured meat in his undergraduate years. Discouraged by the challenges of culturing meat in mass quantities, Ryan decided to pivot towards milk proteins instead.

Upon connecting with Dr. Kaplan, we learned that he had been keen to do cultured meat research for several years but was not receiving financial support for food applications of tissue engineering. We decided to work together to create a fellowship for a food-focused tissue engineering student to be trained in his laboratory. Rather than be project-based, this was an education-oriented fellowship meant to populate the talent pool for cellular agriculture. We received multiple applications for this position over several months.

Natalie Rubio was selected to be the first cellular agriculture PhD student. She is a bit of a New Harvest veteran, having been a volunteer since 2013 and an intern in the summer of 2014. Today, she is a Ph.D. graduate student at Tufts University and a New Harvest

Research Fellow! Natalie is conducting research in the Biomedical Engineering Department under the supervision of Dr. David Kaplan. The Kaplan Research Group focuses on designing biomaterials for regenerative medicine, disease models, and now—tissue engineered foods.

As Natalie learns several laboratory techniques, she will come to design a specific project with Dr. Kaplan. Because she is in regular contact with the other New Harvest Research Fellows, Natalie is in the position to note the gaps in others' research and design a project that specifically addresses an unforeseen neglected area.

With the support of New Harvest and her fellow research fellows, it is hoped that Natalie's work will help progress cultured meat products from lab bench to dinner plates within a matter of years.





Focus Group Perceptions of Cellular Agriculture

Project Dates:

December 2016

Project Lead:

Dave Rejeski

Funds from New Harvest:

\$0

Project Location:

Baltimore, Maryland

In the fall of 2016 New Harvest, in partnership with the Environmental Law Institute, sought out to conduct the first American focus group studies on attitudes towards cellular agriculture and cultured meat. The focus groups were conducted by Hart Research, a firm with specific expertise in conducting public opinion research. The costs for the collaborative project were supported entirely by the science and technology-focused Richard Lounsbery Foundation.

A final report was released in January 2017, entitled “Perceptions of Cellular Agriculture: Key Findings from Qualitative Research.” Excerpts of Isha’s takeaways from the report’s findings can be found below:

I should point out my bias—which is that I don’t have the most faith in market research. In general, I believe market research is useful to test incremental advances—like the colors for the next iPhone—rather than transformative ones—like if prospective users would see value in Twitter.

That said, this type of research has been used to explore public opinion about technological developments with longer term

impacts, such as nanotechnology, synthetic biology, and neural engineering. Focus groups are snap shots. Though they provide rich information, the results cannot be extrapolated to national populations (they do provide important information needed to design statistically robust national surveys). This type of research needs to be updated as the science moves forward and products enter the market to address questions like:

1. Will consumer perceptions change in the time that passes from now and when we actually see products on shelves?
2. How valid is this research if the first products are not, in fact, exact replicas of conventional meat?

That being said, considering that social science research into cultured meat seems to be relatively well-funded (emphasis on "relatively" compared to hard science research) through established research funding channels (at least in Europe, so far), I think these focus groups were a great "base layer" of American research from which we could pull out several ideas for future studies.

Here are a couple of points that stood out to me.

1. "Moral/Ethical Concerns Did Not Surface." It was interesting to note how improved animal welfare was essentially a negligible benefit of cellular agriculture for both focus groups. It has always been a delicate balance for New Harvest to appeal to an animal-welfare focused community (from whom we receive the most philanthropic support today) compared to the general public (from whom consumer interest in cellular agriculture products is required in the future). It would be interesting to conduct further research to see if an emphasis on the moral/ethical benefits of cultured meat might be a deterrent for the general public.

2. Cultured Meat As A Complement To Conventional Meat. As expected, participants in the focus groups seemed to be very concerned that cultured meat would entirely replace the existing livestock industry. Choice was clearly important. My concern, however, is that choice is more about an "opt out" rather than an "opt in," because of the following related point, that...

3. "...People Should Consume Cultured Meat, But Not Me, Personally." I found that, particularly in the college-educated group, that there was a strong acknowledgement that cultured meat and cellular agriculture would be beneficial to the world, with recognition of certain other populations who could be helped by cellular agriculture. But it was not as easy to see a personal interest in consuming cellular agriculture products. I am curious to see if New Harvest's donor community thinks similarly. I am also curious to see what would prompt an individual to be excited to consume cultured meat personally. Do the externalized benefits even matter when it comes to a grocery store decision?

4. A Conflict Between Terminology Preferences And Transparency. I was not too surprised when both groups had generally negative impressions of the term "cultured meat," but I thought it was impressive how relatively accurate their thoughts were when prompted with the term. Considering that there was a strong emphasis on the value of transparency with respect to food science, I wonder if it is more ideal to choose terminology which is less descriptive but more marketable, or terminology which is more descriptive but less marketable. I think a helpful piece of further research would be gathering thoughts from uninformed individuals prompted with various terms, followed by a description of what the term is referring to, followed by a survey of their

feelings regarding the discrepancy between their impressions of the term and the actual product the term was referring to.

5. The Importance Of Who Is Working On Cellular Agriculture.

I have to admit it was frustrating to be behind the one-way mirror while the focus groups assumed that the study was being organized by a large corporation. I suppose we could have guessed that that would happen, but I think it would be very interesting to see how opinions might be different knowing that there is a donor-funded charity advancing a large proportion of cellular agriculture research.

Especially seeing how much individuals and personal stories have become a large part of today's culture, it would be interesting to test who would be more effective at sharing information about cellular agriculture. Dave Rejeski did some research on this for synthetic biology*, examining the role of the messenger (as well as the message) in communicating synthetic biology .

6. Negligible Differences Between Both Focus Groups. The main difference I saw between the groups was a tendency of the college-educated group to over-intellectualize—i.e. talk about what was good for other people, and how they should think, rather than provide their own personal reactions upfront. But I think the personal reactions were more or less the same. This confirmed my personal guiding principle—that it can be misleading to "other" consumers and imagining what "they" might be interested in, as if it is different from your own personal preferences.

7. A Demand For More Information. I was actually a little bit surprised at how negatively the participants responded to the

* <http://www.synbioproject.org/publications/a-guide-for-communicating-synthetic-biology/>

video we showed during the study.* The takeaway for me was that there is a desire for more information about the actual process and technology behind cultured meat. I also wondered how reception might have been different if the video was shown earlier in the study design—is it useful as an introduction, or does it come across as "propaganda" regardless of when it is seen?

8. A General Lack Of Understanding Of The Existing Animal Agriculture System. It would be interesting to see if an outline of the various issues associated with animal agriculture might be a better illustration of the benefits of cellular agriculture rather than stating, independently, the benefits of cellular agriculture.

In the end I thought this study was an excellent starting point for gathering some American perspectives on cellular agriculture and cultured meat. The obvious follow-on to this work would be a national survey built on the focus group findings, which provides a more detailed and generalizable picture of the American population.

* Derek Lau's "Meat/Culture", available at <http://vimeo.com/78403188>

Investigating Celery-Based Scaffolds For Cultured Meat Co-Cultures

Project Dates:

Feb 2017 - May 2017

Project Lead:

Jess Krieger

Funds from New Harvest:

\$0 (Jess Received \$5000 from the Shuttleworth Foundation & \$2000 From Kent State as a Research Award)

Project Location:

Ottawa, Ontario, Canada

Plant-based cellulose scaffolds have been explored by Andrew Pelling's lab in Ottawa as scaffolds for mammalian tissue (you may have seen the famous "ear grown on an apple" that was created in his laboratory). The laboratory prepares plant-based cellulose scaffolds by beginning with part of a plant, then removing the plant cells from the cellulose, a process called "decellularization". Mammalian cell types can then be "seeded" into these scaffolds to grow cultured meat.

Jess* thought that celery might be an interesting scaffold for cultured meat because it could offer an environment similar to where muscle cells would grow in vivo. Celery has elongated tube-like

*Jess heard about New Harvest through a Reddit AMA that Daan, Gilonne, and I did in early 2016. Jess had geared her whole graduate experience towards one day doing cultured meat research, and did not know there was already a community striving towards the same goal. Within moments, Jess was an important part of the New Harvest community, sharing her hands-on expertise in muscle cell culture.

In fall of 2016 Jess told us she was applying for grants to do visiting scholar work at the Pelling Lab in Ottawa. She had received \$2000 in an award from Kent State, but needed more in order for the 4-month stint to be financially viable. Through the Shuttleworth Foundation, I had the opportunity to be a philanthropist myself. Every six months, Shuttleworth Fellows can donate \$5000 of Shuttleworth Foundation funds to any individual or organization of their choosing. Seeing the difference that \$5000 would make for Jess, it was an easy decision to direct the funds to her. While this technically was not a New Harvest funded project, we welcomed Jess into the group of Fellows. After her work in Ottawa, she decided to apply to become a full-fledged New Harvest Research Fellow. That project is listed below this one. - Isha

structures which resemble long muscle fibers, which she thought was a good starting point.

To begin investigating celery's suitability as a scaffold for cultured meat, Jess took some imagery of the cellulose structures and tested their stiffness. She found that celery was about three times as stiff as muscle tissue, which might hinder muscle growth.

She softened the cellulose scaffolds by freezing the celery overnight. The formation of ice crystals in the celery helped break down some of the cellulose structures inside, resulting in softer scaffolds, with a more "rippled" surface. This would probably be a more flexible, and therefore more suitable environment for muscle cells to grow inside.

Jess then cultured muscle cells in the pre-frozen celery cellulose scaffolds. She used a co-culture of an immortalized mouse muscle cell line called C2C12s* and myofibroblasts** derived from pig muscle. Jess' previous work examined how co-cultures of muscle cells with myofibroblasts can enhance muscle formation. She found that this co-culture strategy grew more developed muscle tissue than muscle cells alone. This work shows that many different strategies for cultured meat are possible, including co-cultures with multiple cell types found in muscle and using diverse scaffold materials, such as cellulose from plants.

Many thanks to the Shuttleworth Foundation for supporting Jess's research in Ottawa.

*Mouse-derived C2C12s are the most common cell type used for muscle tissue research today.

** Myofibroblasts are a special type of connective tissue cell that regulates wound healing in the body.



Vascular Tissue Engineering And Bioreactor Design Optimization For Cultured Pork

Project Dates:

June 2017 - May 2020

Supervisor:

Dr. Min-Ho Kim

Funds from New Harvest:

\$105,000

Project Location:

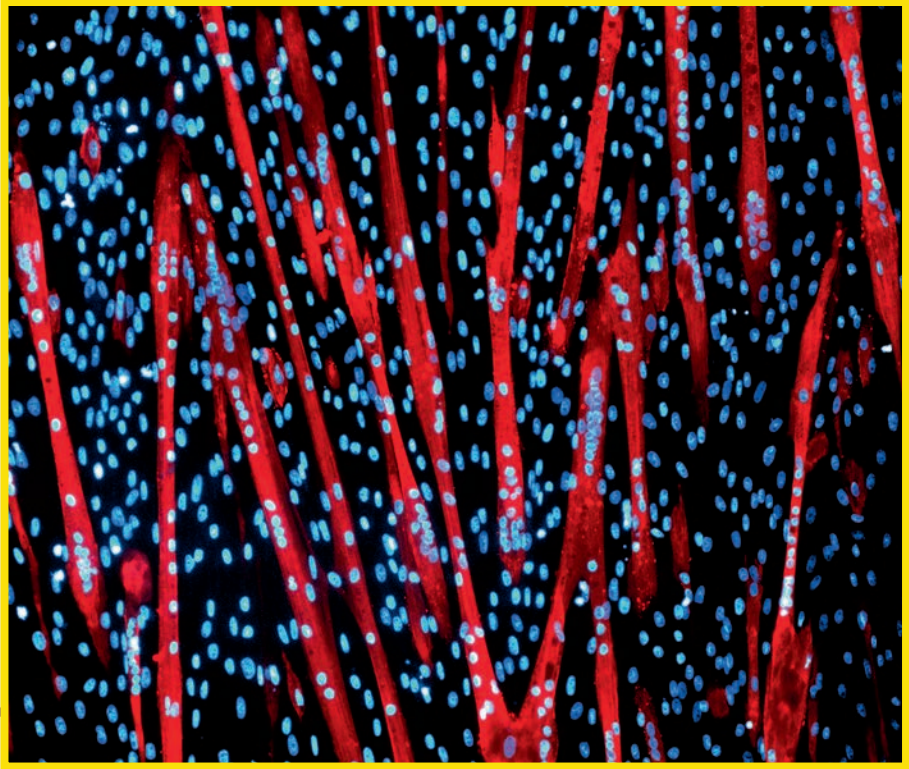
Kent, Ohio, USA
Kent State University

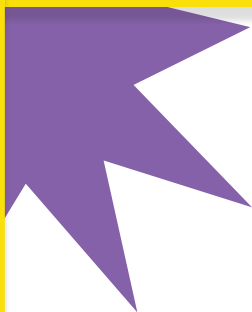
Research Fellow:

Jess Krieger

One of the challenges of producing meat in cell culture is increasing the thickness of the tissue beyond a few micrometers. Cell tissue grows in thin layers in vitro because nutrients from the liquid medium must diffuse into the cells through direct contact. To grow tissue with thickness, nutrients and oxygen must be brought up into the tissue via blood vessels. The process of growing vessels in tissue is called vascularization.

This research sets out to develop a culture system capable of growing vascularized tissue. Jess will first attempt to generate an interconnected network of vessels within an algae-based scaffold material called alginate. The network will be stabilized within engineered muscle tissue with the use of a bioreactor system capable of organizing and maturing muscle fibers through electrical stimulation.





Plant-Derived Scaffolds For Supporting In Vitro At Small and Large Scales

Project Dates:

Sept 2017 - Aug 2020

Supervisor:

Dr. Andrew Campelling

Funds from New Harvest:

\$184,500

Project Location:

Ottawa, Ontario, Canada
University of Ottawa

Research Fellow:

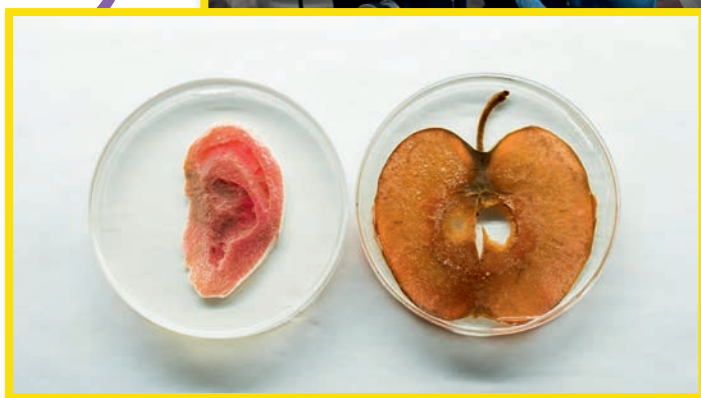
Santiago Campuzano

Currently, scaffolds for mammalian tissue culture are derived from animal products or are chemically synthesized. These materials can be problematic for cultured meat production based on their source, as well as their price points.

Cellulose is an abundant, sustainable, and easily sourced biopolymer. It is the material that makes up the cell walls of plant cells. Aside from water, cellulose is what provides plants with their structure. The Pelling Laboratory has already demonstrated that apple-derived cellulose can act as an ultra-low cost and efficiently produced three-dimensional scaffold. They have shown that cellulose biomaterials can support the three-dimensional culture of mammalian cells and promote cell growth and multiplication while maintaining scaffold shape and mechanical properties for several months.

Cellulose scaffolds can be extremely valuable for cellular agriculture applications. Aside from being inexpensive and edible, plant-based cellulose scaffolds can control shape, texture, mechanical properties, and the organization of cells. The greatest challenge in developing cellulose scaffolds is exploring the sheer number and variety of plant species as sources of scaffolding material.

This research will explore five candidate plant-derived scaffolds (Asian pear, carrot, rose petals, asparagus, and mushroom) for their ability to support muscle cell growth and maturation with and without animal-serum. The team will also develop a new protocol to enable the production of cellulose hydrogels that can be easily poured into large-scale molds.



Cultured Meat Bioprocess Design

Project Dates:

Oct 2017 - Oct 2021

Supervisors:

Dr. Marianne Ellis, Dr. Paul deBank, Illtud Dunsford

Funds from New Harvest:

£75,200

Project Location:

Bath, Somerset, UK
Bath University

Research Fellow:

Scott Allan

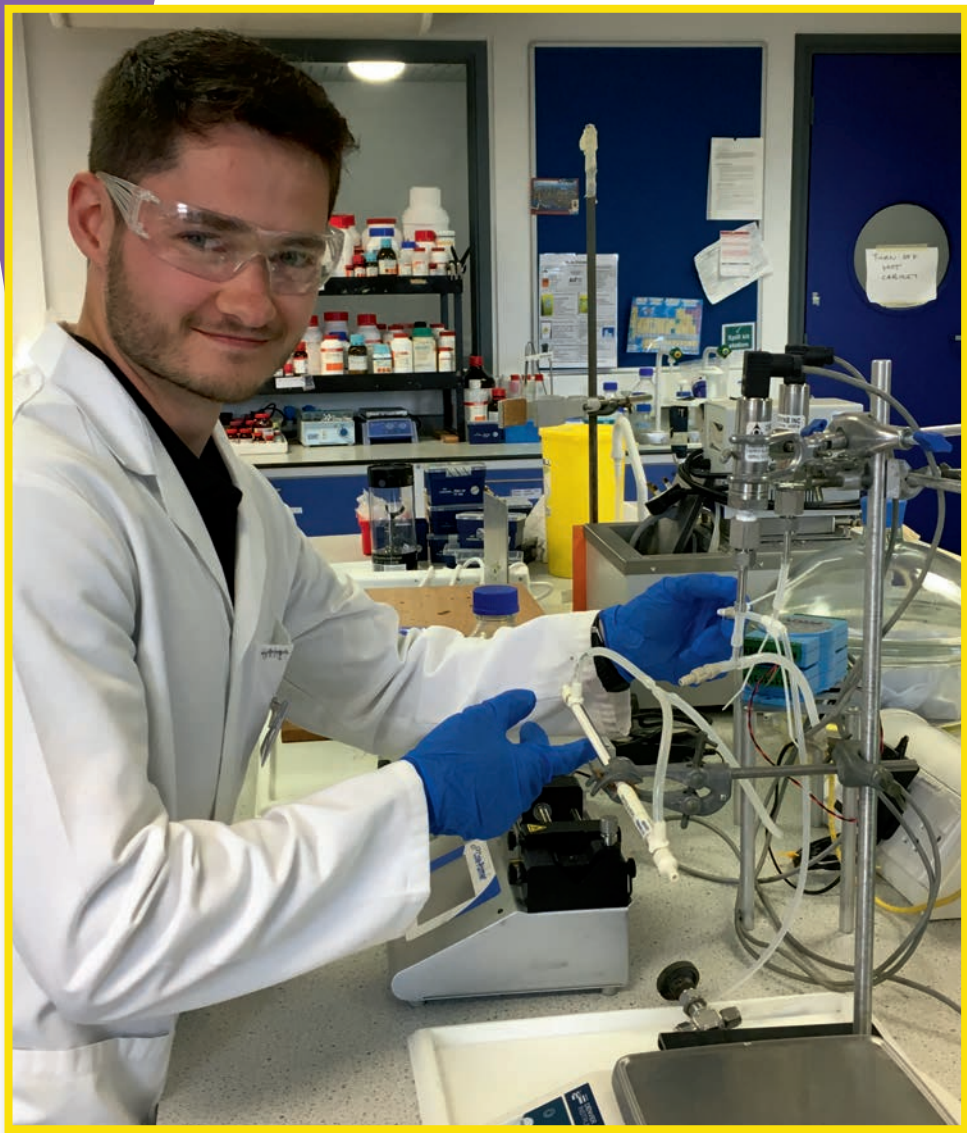
Bioreactor design and control are well established in engineering disciplines like pharmaceuticals and medicine but are completely new for cultured meat. To date, the bioreactors used for cultured meat production have been of a lab scale, typically culture flasks and small-scale bioreactors up to 10L. To reach industrial scale production of cultured meat, large bioreactors must be designed. In order to design an appropriate bioreactor, certain parameters must be understood.

These fundamental parameters include:

1. Reaction kinetics (how quickly muscle cells will grow, divide, and mature),
2. Transport phenomena (how nutrients will enter the cells, how waste products exit),
3. Mass transfer limitations (the efficient flow of media over cells)
4. Metabolic stoichiometric requirements (what the inputs (food) and outputs (waste products) of cultured meat production will be)

To date there is no such data for muscle cell cultures for meat. This project will determine these fundamental parameters for cultured meat production, becoming the crucial basis for mass production. This research is the necessary first step in scaling cultured meat production. All results will remain open access for use in research and industry.





2016 Moments



Here's a look back at some of our favorite moments of the past year!



*Atnour first New Harvest
Fellows' Retreat in Ottawa,
March 2017*

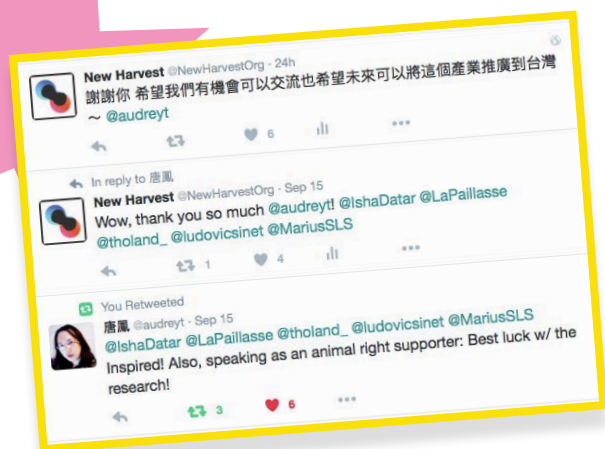
*Erin and fall '16 intern
Mike after giving a lecture
to some students at
Parsons School of Design*



*Isha and Erin with
donor Adam Sender in
summer 2016*



*Meeting Margaret
Atwood at a talk about
the biotechnology used
in her novel, Oryx and
Crake, and then tweeting
with her after!*



That time Audrey Tang, Digital Minister of Taiwan, tweeted at us!



Natalie, Marie, and Jess making a stop in Amsterdam en route to the Cultured Beef Symposium in Maastricht, The Netherlands in fall 2016.

Isha and Erin making a live appearance on Cheddar TV



The summer '16 crew attending Food Loves Tech (with our friend Rob Bolton)



A fun illustration of Isha and Erin by artist Vesna Asanovic in the Bay St. Bull magazine



Shojinmeat including a shoutout to New Harvest in their zine



Our conference producer Morgan's spiffy New Harvest-themed manicure!



Selected Writings

When “Cellular Agriculture” Got It’s Name



*We rarely talk about the origins of the term of cellular agriculture, probably because we imagine that the naming of a field of research would take place at a large, serious meeting, by a panel of upper echelon scientists and officials. In fact, the term "cellular agriculture" arose from the grass roots, in the New Harvest Community group on Facebook!

I remember the day I knew the terminology had legs; I was on a conference call with the National Science Foundation, hearing "cellular agriculture" being repeated back to me by NSF employees with a suffused casual confidence that implied that "cellular" and "agriculture" were words that had been paired for years—definitely not awkwardly fastened together in a Facebook thread.

The external validation has helped me comfortably incorporate "cellular agriculture" and "cell ag" into my everyday lexicon without a feeling of pretension. —Isha



Isha Datar

March 27, 2015 · Brooklyn, New York

Ok so NH is really trying to establish the academic discipline and industry focused on "animal products without animals"... any ideas of what a sexier name for that discipline could be?

6 Likes 75 Comments



Like



Comment



Share

Ron Shigeta, Anke Hagen, Isha Datar and 3 others like this.



Ben Wurgaft I have so many questions about this! I think we discussed this briefly at the meeting in Menlo Park. How are we defining "discipline," here? What's the broader goal, and is it based on a perception of the way existing scientific disciplines do or don't funnel personnel and funds into this research? I'll leave it there for now, but mark me down as "very interested."

March 27, 2015 at 8:40am · [Like](#)



Isha Datar I think it's about buzzwords. For example, "synthetic biology" doesn't really mean anything new but since it has a new, hot name, everyone wants to jump on that bandwagon.

March 27, 2015 at 8:41am · [Like](#) · 1



Ben Wurgaft I think I'm still a step behind you – what's the strategic goal of such a branding effort? Thanks!

March 27, 2015 at 8:43am · [Like](#)



Isha Datar Well say we decide to start a centre for excellence of this at a university, which we are in the process of doing. What would the centre be called?

March 27, 2015 at 8:46am · [Like](#) · 4



Ben Wurgaft Gotcha. I suppose my first response was "this is an interdisciplinary thing, rather than a discipline," so I wanted to ask you how you wanted to define the endeavor itself.

March 27, 2015 at 8:48am · [Like](#)



Isha Datar But don't many disciplines begin as interdisciplinary?

March 27, 2015 at 8:49am · [Like](#) · 2



Ben Wurgaft Well, that's a tricky question. It's also very different in the lab sciences and engineering than in other fields. Because I'm a social-scientific stickler, I hesitate to call the effort to produce animal products without animals a "discipline" – it seems to combine a mass of skills and techniques from different fields. Perhaps a scientist would feel differently about this. What I'm curious about, is why one would find it desirable to brand this as a discipline at all – isn't it just as legitimate if it's interdisciplinary, or if it's a set of collaborative projects conducted by people in different fields, perhaps coordinated by a centre for excellence?

March 27, 2015 at 8:57am • Like • 1



Tom Ben Arye Cultured nutrition

This name "cultured" is already in use, it's catchy, it fits most of the products and it has good connotations.



March 27, 2015 at 1:04pm • Edited • Like • 5



Barnaby Dawson Synthetic animal tissues

March 27, 2015 at 9:42am • Like



Mallory E. McLaren Culture Bioproducts?

March 27, 2015 at 9:53am • Like • 1



Mallory E. McLaren Cultured Biofabrication

March 27, 2015 at 9:53am • Like • 1
























Mallory E. McLaren Consumer Product Biofab Dept. 😊

March 27, 2015 at 9:54am • Like • 1



Natalie Rubio Animal-Free Food Innovation

March 27, 2015 at 10:26am • Like • 1

-  **Natalie Rubio** Engineered Nutrition
March 27, 2015 at 10:26am · Like ·  2
-  **Bruce Chou** animal template foods department.
March 27, 2015 at 10:29am · Like
-  **Isha Datar** Not all animal products are food, too
March 27, 2015 at 12:59pm · Like
-  **Tom Ben Arye** Cultured consumables/goods?
March 27, 2015 at 1:03pm · Like ·  2
-  **Sherrie Tullsen-Chin** Post-animal consumables.
March 27, 2015 at 1:05pm · Like ·  2
-  **Kevin Schneider** "Post-animal"....I really like that. Post-animal economics?
March 27, 2015 at 1:13pm · Like ·  1
-  **Isha Datar** Kevin Schneider economics?
March 27, 2015 at 1:15pm · Like
-  **Isha Datar** I like cultured consumables Tom Ben Arye has a nice ring to it 😊
March 27, 2015 at 1:16pm · Like ·  2
-  **Isha Datar** Cultured Consumer Products (where either the product or the consumer is the cultured one haha)
March 27, 2015 at 1:21pm · Like ·  8
-  **Sherrie Tullsen-Chin** I like cultured consumables too but it doesn't indicate any distinction from cultured products that are not replacements for animal products.
March 27, 2015 at 1:22pm · Like ·  1
-  **Rachel Graham** I really liked cultured nutrition
March 27, 2015 at 1:34pm · Like ·  5
-  **Isha Datar** Cellular Agriculture
March 27, 2015 at 1:49pm · Like ·  8
-  **Kevin Chen** just thinking aloud.... Isn't there already a name for this? like Sustainable Food Production (except more specific, I guess?) Is the focus on food replacements, or alternatives or novel foods? Alternative dietary sciences? Food design? Dietary design/... [See More](#)
March 27, 2015 at 1:55pm · Like ·  2
-  **Isha Datar** Agriculture means "field growing" or "field cultivation", horiculture means "garden growing" I wonder if we can find some kinda latin thing
March 27, 2015 at 2:15pm · Like ·  3



Travis Callue AgriCULTURED. 🤖

March 27, 2015 at 2:23pm · Like · 🍷 7



Barnaby Dawson Cultured animal tissues. That covers in vitro meat, artificial leather and more or less any product with animal cells in it that didn't immediately come from an animal.

March 27, 2015 at 2:52pm · Like



Maya Kaul Biosustenance? Bionutrition? (that leaves out leather, though). Biodesign?

March 27, 2015 at 2:56pm · Like · 🍷 2



Barnaby Dawson Can we have a more precise definition of what we're describing exactly? In particular what things should be included: My impression is that we're trying to describe products made from animal tissues grown in culture. Is that right or are we including other products too? If so what?

March 27, 2015 at 3:05pm · Like



Isha Datar I was thinking animal products grown in culture. Or maybe wide enough to include non-animal products grown in culture ie cotton grown by bacteria even

March 28, 2015 at 7:19am · Like



Kevin Mayo +1 Cellular Agriculture because it can (and would) be referred to as 'cell-ag', which lends a layer of credibility and confusion to conversations between those 'in the know' and others.

March 28, 2015 at 7:47am · Like · 🍷 4



Natalie Rubio +1 cellular agriculture !

March 28, 2015 at 11:11am · Like · 🍷 5



Ryan Pandya Agreed, that's the best one I've seen so far

March 28, 2015 at 11:47am · Like · 🍷 3



Isha Datar Cell also means "small room" in latin and maybe that's also a roundabout way of indicating that you can cultivate food in a small room rather than in a field

March 28, 2015 at 3:52pm · Like · 🍷 2



Barnaby Dawson It seems to me that cellular agriculture could refer to beer, cheese, silage etc. Do we want the term to cover those things or only the newer technologies?

March 28, 2015 at 4:07pm · Like



Trent Erikson 'Cellular agriculture' has that magic stickiness that immediately puts it on the tip of your tongue. (Also, don't forget about 'techno-veganism'! ;))

March 28, 2015 at 4:51pm · Like · 🍷 2



Isha Datar Maybe that's not a bad thing?

March 28, 2015 at 4:58pm · Like



Maya Kaul If you still want Latin or Greek, my favorite are propecuculture: cultured beyond "herd animals", kadiculture cultured in a container, or kardainiculture: cultured for the product (i.e. instead of using animals to get meat or milk or anything like that... [See More](#)

March 28, 2015 at 5:13pm · Like · 2



Trent Erikson If you think science/technology buzzwords like 'data mining' or 'personal genomics', there is often an ordinary, commonly used word accompanied by a scientific/technological word. 'Cellular agriculture' follows that pattern.

March 28, 2015 at 6:01pm · Like · 1



Isha Datar What about microbial agriculture

March 28, 2015 at 6:03pm · Like · 1



Isha Datar Actually cultured meat isn't that...

March 28, 2015 at 6:03pm · Like · 2



Nick Bencivenga +1 cellular agriculture.

March 28, 2015 at 6:15pm · Like · 2



Meera Zassenhaus my roommate suggests bioculture

March 28, 2015 at 6:47pm · Like



Isha Datar There isn't any culture that isn't bio though

March 28, 2015 at 6:49pm · Like



Karina Barbara I scrolled down not because I had an idea but wondering what others would say. And I am all with cellular agriculture. Cellular sounds sexy (ok maybe I am being funny...but seriously I like the sound of it).

March 28, 2015 at 10:41pm · Like · 2



Erin Kim I like cellular agriculture, and perhaps, going off of Kevin Schneider's idea, "post-animal sciences"?

March 29, 2015 at 1:46am · Like



Trent Erikson 'Post-animal produce' for an alliteration

March 29, 2015 at 4:01pm · Like



Ryan Pandya We shouldn't hold ourselves back with a reference to animals. These are foods that don't need to have anything to do with animals, and in a hundred years it should seem disgusting and antiquated to ever associate our food system with animals

March 29, 2015 at 5:29pm · Like · 3



Ryan Pandya Imagine if cars were called "autohorses" it would be so stupid

March 29, 2015 at 5:30pm · Like · 5



Kevin Schneider But we still use the term "horsepower" to describe an aspect of the car: old ideas linger in our speech (and thus our ideas), and "familiarity" can be huge in marketing consumer products

March 29, 2015 at 5:41pm • Like • 3



Isha Datar Yes, and the foods would be beef, pork, chicken, milk, eggs... which are exactly the same. I agree, I don't want to be held to the antiquated idea of animal ag by referencing it

March 30, 2015 at 8:25am • Like



Mirko Betti Isha, we might be able even to skip the "cell factory" concept for producing food. The longest and more open horizon I see is: molecular agriculture.

March 30, 2015 at 11:29am • Like • 1



Ben Wurgaft Ryan, I think "autohorse" is amazing and I plan to start using it.

March 30, 2015 at 12:01pm • Like • 4



Isha Datar Mirko Betti Molecular Agriculture does already sound similar to Molecular Gastronomy

March 30, 2015 at 12:18pm • Like



Karina Barbara My autohorse needs a wash, and I gotta change his snow hooves back to all season hooves.

March 30, 2015 at 12:41pm • Like • 1



Patrick Mogianesi Biotechnology Production?

March 30, 2015 at 9:14pm • Like



Isha Datar Mirko Betti there appears to be a Center for Molecular Agriculture but I feel like the name is not appropriate for what it was designed to do:

<https://ag.purdue.edu/plantsciences/pages/molecularag.aspx>



Purdue Agriculture

Purdue University's College of Agriculture, or Purdue Agriculture, is one of the world's leading colleges of...

AG.PURDUE.EDU

April 1, 2015 at 10:28am • Like



Trent Erikson Does cultured meat count as molecular biology?

April 1, 2015 at 12:58pm • Like



Tom Ben Arye Cultured meat is a large multidisciplinary project, some of it is considered to be molecular biology.

April 1, 2015 at 1:06pm • Edited • Like • 2



Anke Hagen Yes, other parts of it are similar (as far as the techniques are concerned) to regenerative stem cell biology or simply stem cell research.

April 1, 2015 at 1:38pm · [Like](#)



Marty Brandon My feeling is that the procedural difference deserves the emphasis. It shouldn't be defined by meat. In vitro food production is to traditional agriculture what 3D printing is to subtractive manufacturing. We'll also be making in vitro plant-based p... [See More](#)

April 1, 2015 at 2:47pm · [Like](#) · [1](#)



Barnaby Dawson Biofabricated consumables

April 1, 2015 at 3:14pm · [Like](#)



Barnaby Dawson Biofabrication is an existing term defined: "Biofabrication can be defined as the production of complex living and non-living biological products from raw materials such as living cells, molecules, extracellular matrices, and biomaterials"

By adding consumables we focus on food and consumer products rather than medical or purely research uses of biofabrication.

April 1, 2015 at 3:17pm · [Like](#) · [3](#)



Isha Datar Isn't neoculture just a latin term for New Harvest hahaha

April 1, 2015 at 4:37pm · [Like](#) · [2](#)



Maya Kaul ^Basically!

April 1, 2015 at 4:53pm · [Like](#) · [2](#)



Isha Datar Andy Vrbicek we were thinking more about the whole discipline of cultured animal products not just meat.

April 2, 2015 at 6:02am · [Like](#)



Marty Brandon I don't think PR concerns should be the primary consideration for labeling a new field of research.

And my guess is that focusing on the process, rather than the end-product, will also futher your marketing objectives. The most straightforward way to communicate that in vitro meat is like regular meat is to avoid presenting it as something categorically different.

April 2, 2015 at 2:28pm · [Like](#)



Erin Kim Ben Wurgaft!

June 30, 2015 at 10:09am · [Like](#)



Isha Datar Gi d'Origny and I have been using cellular agriculture and it's been going well! Many act as if they've heard of it before.

June 30, 2015 at 11:53am · Edited · [Like](#) · [3](#)

A Primer On Cultured Meat Production

The concept of cultured meat*—meat produced from cell cultures rather than whole animals—has been a topic of conversation for decades, regularly appearing in science fiction and speculative writings about the future of food. Often cited is Sir Winston Churchill's quote from an essay titled *Fifty Years Hence*, first published in 1931: "Fifty years hence, we shall escape the absurdity of growing a whole chicken in order to eat the breast or wing by growing these parts separately under a suitable medium." Sadly, Winston's timelines were a bit optimistic, and we weren't chowing down on cultured meat in the early 80s. Instead, since Churchill's prediction, the "absurdity of growing whole chickens" and whole animals in general, only became more absurd.

A 2007 report by the Food and Agriculture Organization estimated that 56 billion land animals are raised for food each year globally. It is estimated that intensive animal agriculture (aka factory farming) accounts for 39% of the global production of beef, veal, sheep, goat, pork, and poultry meat. The scale at which we are raising animals for food is such that 70% of all agricultural land and 29% of our global freshwater footprint is devoted to animal agriculture, making it one of our most resource intensive activities. Animal agriculture is also incredibly degrading to our environment, being a leading cause of deforestation, water pollution, desertification, and climate change. Furthermore, the conditions created in factory farms create ideal environments for the rise of epidemic viruses, antibiotic resistance, and food borne-illness causing bacteria. And surrounding this is the general unease that many meat-eaters feel about consuming animals, especially those animals raised in less-than-humane conditions.

The conjectural benefits of cultured meat come from the idea that controlled production of muscle tissue avoids several of the issues

*Many of our supporters will be familiar, generally, with what is required to produce cultured meat. For the sake of anyone new to the concept who has happened to pick this up, or for those who would like a short and sweet refresher, this is for you. If you would like to go deeper into the science, I'd recommend starting with the paper I published in 2010, *Possibilities for an in vitro meat production system*, which I pulled some of the following content from. The paper is as relevant today as it was 7 years ago. —Isha

associated with raising whole animals. Cultured meat production should be more efficient, because only the desired tissues are being grown; safer, because animals' bodies can no longer be used to incubate viruses and bacteria; more environmentally sound, because closed conditions minimize external polluting effects; and more humane, because animals should only be required as a source for initial cell culture samples.

While only time and scientific inquiry will tell if and how these benefits manifest and what unforeseen dilemmas arise, cultured meat remains science worth pursuing. As we reach planetary limits with current agriculture systems, enter an era of climate change, and face a growing global population, we need to investigate a wide range of options to secure our future food supply.

So, how do we produce cultured meat?

Let me preface the remainder of this essay with the clarification that scale production of cultured meat does not yet exist. What follows is speculative, based on current tissue engineering processes. You will find that the outline is quite broad and quite flexible so it could accommodate several different potential cultured meat production processes.

The basic schematic of cultured meat production consists of four main elements: cells, scaffolds, media, and bioreactors. Cells make up the “meat” of what you’re trying to grow, usually muscle cells but perhaps other types like fat or connective tissue cells for functional or flavoring purposes. Muscle cells require attachment to a surface to mature into long muscle fibers, and a scaffolding material provides that structure. Muscle tissue can also grow only about 0.2mm thick in culture, so a scaffold can also provide a means for the muscle tissue to grow thicker by providing channels for nutri-

ents to penetrate the tissue, mimicking or replicating blood vessels. Cells growing on a scaffold require a liquid media to provide all the necessary nutrients that cells need to grow and divide. And finally, the cells, on scaffolds, in media, grow within a bioreactor, a vessel that provides the ideal environment for cell growth and maturation.

Cells are the “starter culture” for cultured meat production, and will probably be from an agricultural animal unless you’re trying to grow some more exotic meat products. There are options and compromises in choosing your cell type. Choosing a more stem-like cell means the cell will double many more times, but may be hard to direct into becoming muscle tissue; choosing a muscle-destined cell will double fewer times, but will become muscle tissue more fully. It is relatively simple to collect a sample of muscle cells from agricultural animals through a simple biopsy. It is harder to collect and establish stem cells, and for years, scientists have been stumped as to how to maintain stable stem cell lines for several farmed animal species.*

There are different philosophies on how often biopsies will be required; some researchers suggest regularly collecting fresh cell samples already destined to become muscle; others suggest establishing a stem cell culture so that samples will never need to be collected again.

There is also debate about if the cell cultures should be genetically manipulated. For basic cell culturing, genetic manipulation is not required, however if any additional qualities want to be integrated for research or product purposes, genetic manipulation may be of use.

*There are several papers on this topic, the title of this one probably most helpful to the point I’d like to get across: Gandolfi, F., Pennarossa, G., Maffei, S. and Brevini, T. (2012), Why is it so Difficult to Derive Pluripotent Stem Cells in Domestic Ungulates? *Reproduction in Domestic Animals*, 47: 11–17.

Another set of options is pure culturing vs. co-culturing. For example, if you were producing a cell cultured hamburger, you may want to grow a culture of muscle tissue in one bioreactor and a culture of fat tissue in another, then combine them to create the final, edible product. If you wanted to co-culture, you could grow the muscle and fat tissue within the same bioreactor. The benefits of one strategy over the other aren't yet clear, but co-culturing could be helpful in moving away from animal-based media, as you will see below.

Scaffolds must provide a large surface area for muscle cell growth and attachment, be flexible enough to allow for the spontaneous contraction of muscle fibers, and maximize the cell's exposure to medium. There can be a wide range of shapes, materials, and characteristics to meet these needs. There is a difference of opinion as to if the scaffolding material will be removed or remain part of the meat product.

To maximize surface area, the shapes most often discussed are sheets, threads, beads and sponges. Sheets and threads offer a means for stretching the muscle tissue, which may aid in muscle fiber formation, and may be easier to remove from the muscle culture. Beads and sponges would be harder to remove and would need to be made of an edible material that could remain in the final product. Textural elements on the scaffold could help muscle fibers attach, and deeper grooves could facilitate the flow of nutrients into scaffolding materials, providing sites for vascularization* to take place.

Scaffolds could be made of several different types of materials. Edible scaffolds that work routinely well are collagen and chitosan, which are unfortunately animal based. Plant based scaffolds like alginate or cellulose offer many good qualities but present some ad-

*Vascularization is the formation of blood vessels, or in this case, medium vessels, to assist in bringing nutrients and waste products in and out of tissues.

hesion challenges compared to the animal-based scaffolds. Inedible scaffolds may offer interesting qualities—like electrical conductivity to stimulate maturing muscle fibers, or coatings that allow cell cultures to be easily removed once the growth process is complete.

Perhaps the most difficult task in designing an in vitro meat production system is determining the best culture medium formulation. The medium should support and promote growth while being made of affordable, edible components available in large quantities. Medium composition will be a substantial cost determinant, and I've said it before and I'll say it again: the inability to create a sustainable, affordable media could be a deal breaker for cultured meat.

To date, the status quo of cell culture medium includes animal sera, the most common being fetal bovine serum (FBS). As the name implies, FBS does not lend itself well to consumer acceptance or large-scale use, and, as an animal product from fetal calves, it contradicts the problems of animal agriculture that cultured meat sets out to address. Because FBS is sourced from animals there is high batch-to-batch variance and danger of contaminants. Researchers working with FBS are advised to use a single lot number for an entire experiment because of FBS' high variability. Even beyond cultured meat production, an inexpensive, reliable replacement of FBS would be transformative for the field of tissue engineering.

There are many serum replacements and serum-free culture media available on the market today. The challenges with these products are that:

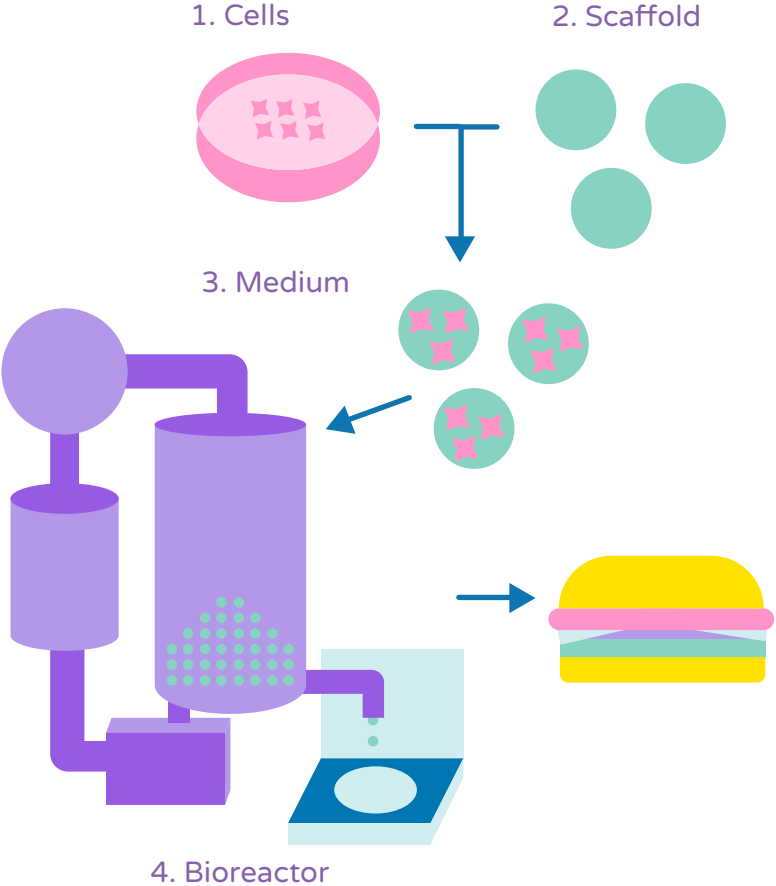
1. They tend to be specific to biomedically-relevant and not agriculturally-relevant cell types.

2. They tend to be copyright protected, making it nearly impossible to understand the formulation composition, and
3. They often contain animal products. Because we routinely see serum-free media designed for specific cell types, it is likely that they will have to be designed specifically for the animal cell cultures that are to be used for cellular agriculture.

Co-cultures could offer an interesting complement to medium composition. Different cell types such as liver cells excrete growth factors that might be needed for neighboring muscle tissue. It is already common in tissue engineering to use a “feeder layer” of a different cell type, often fibroblasts, to provide nutrients for the target cells cultured atop it. The goal of a bioreactor is to provide an environment that promotes the growth of tissues with increased volumes than what is achievable in a culture flask. Key to this is the efficient delivery of nutrients and oxygens to the cultured tissue. There are several existing bioreactor designs from the pharmaceutical industry that could be applied to cultured meat production. Before bioreactors can be designed and built, an understanding of the specific needs of cultured meat tissue is required, such as what inputs of nutrients and oxygen are required, what the outputs will be, and what kind of laminar and shear stresses the cultured tissues can bear.

Developments in tissue engineering, stem cell research, and biomaterial engineering have placed the concept of producing cultured meat within the realm of possibility. What remains to be studied are:

1. The differences between biomedical applications of tissue culture and the agricultural applications, such as the establishing agricultural animal cell lines and investigating scalable, plant-based scaffold materials and media ingredients, and
2. Scaling.



These are enormous areas of research which the small but growing cultured meat research community is chipping away at daily. In terms of an order of events, to us it makes the most sense to establish the animal cell lines that will become the “starter cultures” for cultured meat production, then design media and scaffolding systems around those cell lines, then bioreactors around the cell-scaffold-media systems.

Because of the wide range of possibility in each of the main elements of cultured meat production, there are a huge number of iterations of what cultured meat production can look like at scale. Even after an initial production system is designed, there will be much room for innovation into the future, like different systems for different types of products (ground meats like hamburger vs. structured meats like steak) or different types of species (chicken and turkey vs. beef and pork).

A Letter From Marie*

Dear Isha,

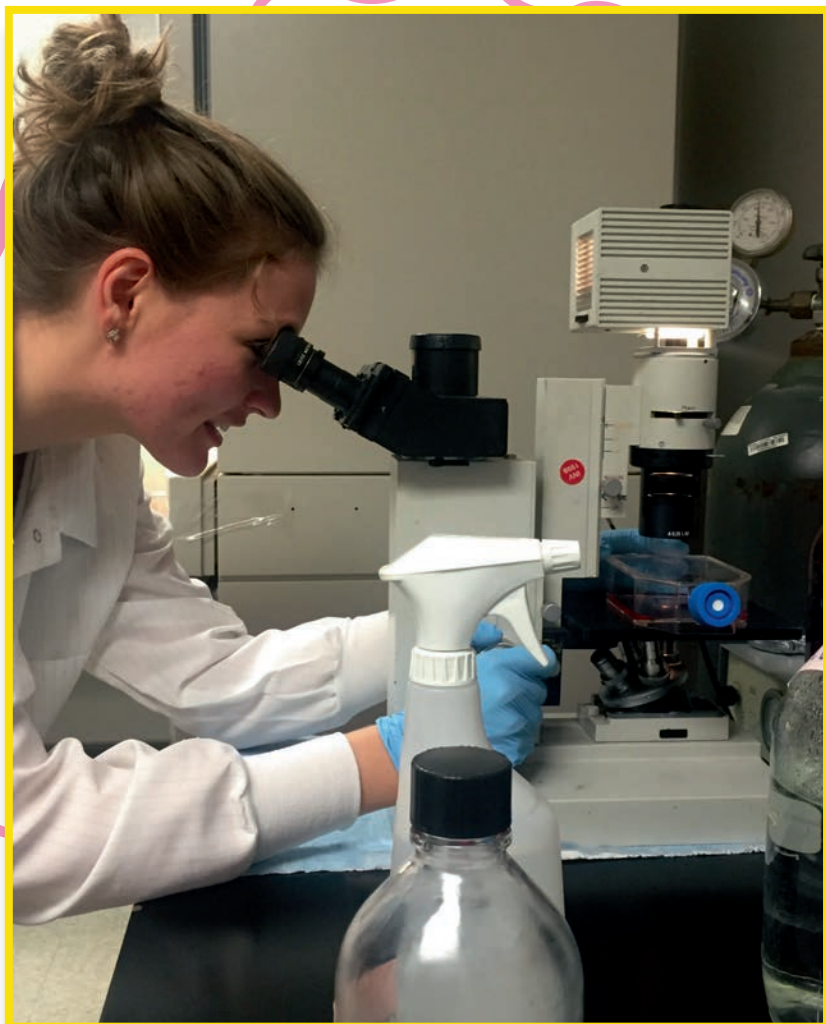
Today we euthanized a baby turkey to create a primary culture cell line. This was a very difficult thing for me to accept, as I am sure it is for you. I wanted to give you some details about what happened, and what we can do in the future to prevent it. I also wanted you to know the whole story, in case others who are concerned about animal welfare have questions regarding the necessity of this decision. The idea of cellular agriculture is to biopsy muscle tissue from an animal without harming it. I was really hoping that this was something we could do, and actually had a veterinarian lined up to perform the procedure under anesthesia. My first thought was that this would be the most humane option, but it actually depends on the situation.

I am still unable to find a refuge that would be willing to take the turkey after the surgery. The one place I was able to get a hold of said that they didn't feel comfortable because the turkey would be purchased from a farm (and therefore would be supporting the agricultural industry) and that the initial research would not be "cruelty free" (as we are still using fetal bovine serum, horse and chicken serum, trypsin from pig pancreas, and gelatin). While all of these ingredients will eventually be replaced with animal free

*When Marie first got in touch with me in early 2016 to be a Research Fellow, I initially turned her down. She was almost, just almost, about to be accepted into veterinary school, and I felt that she may be more committed, in the long term, to becoming a veterinarian rather than a cellular agriculture scientist. Her resume is like a walk through the zoo—she's worked with tigers, bears, wolves, horses, and, I was pleased to see, gibbons. I was worried she would find working with animal cells to be far less rewarding than working with animals.

But she persisted. And she put together an incredible research proposal with the ideal supervisor, in the ideal university, in the ideal department. It was clear that she was driven to become a cultured meat scientist, and she knew how to go about it.

Marie comes to this work as an animal lover, and I was not entirely sure how comfortable she was going to be with some of the inevitable procedures that she would have to face during her work. Nevertheless, she began her research in April 2016. She sent me this letter a couple of weeks later. —Isha



products, the owner of the refuge was still unwilling to participate. As an animal loving vegan, I personally understand her concerns. However, I believe that some sacrifices must be made in order to make this world a better place, and I wish she would have been more open minded for the sake of the turkey and the future that cellular agriculture will bring.

Rehoming the turkey after the procedure was not our only issue. The type of turkey we used has been naturally selected to produce a large amount of muscle over the 28 weeks that he is alive before slaughter. As horrible as it sounds, allowing these turkeys to live past 28 weeks is actually an animal welfare issue. Their muscles become too big for their legs to support, resulting in chronic pain, foot malformations, and broken bones. Even if we had performed the surgery and brought this baby turkey to a refuge, he would have had a very difficult life.

Additionally, he was going to be used in a study to test how many birds can be fit into a certain amount of space without effecting product yield. If we hadn't euthanized him today, he would have spent the next 28 weeks crammed in a small space with other turkeys, only to be slaughtered in the end. I honestly think that it was better for him this way. His life would have been extremely difficult, and this research not only has the potential to save billions from slaughter, but it can end the reasoning behind studies that promote increased animal farming density.

I have learned a lot from this experience, and I hope that future muscle sources will be done without the need for euthanasia. Just in case we need to redo this primary culture, I will be asking around to more refuges (including ones that aren't vegan) and looking for a breed of turkey that will be able to live a healthy adult life.

This sweet little guy will not have died in vain, but I will try my very best to make sure it will not need to happen again!

This was a sad day, but it was also very exciting! We have officially begun growing cells from a primary source, and should see results immediately. If anything, this experience has just made me even more passionate about this research and reminded me of how unimaginably important it is. I have attached some pictures of the lab work we did today, and there will be more to come as the research continues! Please let me know if you have any more questions, otherwise thank you for your time and support, and I will talk to you soon* :)

Best,
Marie

*(Oh, and in April 2016 Marie also was accepted into veterinary school. She turned down the offer.)

We Closed Our First Research Project*

On May 1, 2017 New Harvest discontinued the research conducted by Abi Glencross at King's College London focused on 3D vascularized tissue for the production of cultured meat. It was the first New Harvest-funded Fellowship Project, and it began in November 2015.

A variety of situational factors made this project no longer an effective use of donor dollars. Some of the reasons for discontinuing this work include:

1. An ambitious project that was not meeting the proposed timeline
2. Challenges of the Research Fellow addressing a more “unconventional” approach to tissue engineering,
3. Inadequate research support in this new field from the existing scientific community. New Harvest has made several improvements to the Fellowship program based on following the progress of this project.

*The day Abi called me to confirm that she, too, did not think her project was working was an emotional one. Not in the sense that it was particularly upsetting, or sad, but rather that I found myself carrying an interesting blend of feelings. On one hand, there was this upfront mild panic that New Harvest had done something wrong, but that was diluted by a sense of appreciation, that we had fostered a rapport with our researchers such that they could feel comfortable sharing less-than-ideal news; as well as a sense of pride, that we had already begun to work through many of these issues, and that, in our early documentation, this was already pinpointed as a potential outcome of the project.

Not long after the call I was calmed, comforted, and excited to report the news to our donors. We had already made so much progress based on Abi's experiences and had not yet shared it. This was not bad news. This was evidence that New Harvest had a feedback mechanism for self-improvement.

Our donors saw this story first. I think we got more offers to fund research projects that day than any other. —Isha





Background

In 2015, New Harvest received a proposal to fund a PhD in cellular agriculture—the first of its kind in the world—from a student at King’s College London named Abi Glencross.

The proposal was vetted by two independent reviewers who acknowledged that the project was ambitious. Reviewers suggested diligently following the progress of the research to ensure that the aims of the proposal were being met.

Abi bravely went into uncharted waters with her study of scaffolding and vascularization of cultured meat, in the hopes of getting closer to culturing structured cuts of meat (an advanced step from the “ground meat” muscle fibre texture of the prototypes produced thus far).

As time went on, the uncertainty surrounding the outcomes of this project became increasingly apparent. Additionally, Abi was experiencing challenges being the sole student in her country, let alone institution, who was conducting scientific research in this particular field. Efforts were made to remedy Abi’s situation—a visiting scholar opportunity abroad, a redirection of the project’s parameters—but they did not suffice.

In April 2017 Abi and the New Harvest team decided to discontinue this project. It was the best way to proceed both for Abi, personally, and for New Harvest to make the most responsible use of its donor-funded research grants.

Logistics-wise—New Harvest will receive a full copy of Abi’s laboratory notebook and will be working on how to best share the results that she obtained during her time as a fellow. Any unused funds will be returned to New Harvest from King’s College.

Learnings and Implemented Changes

Throughout the course of Abi's project, New Harvest has made several improvements to its Research Fellow program.

1. Disbursing Research Funds In Shorter Intervals

Abi's research was funded on a yearly basis. As of April 2016, New Harvest began disbursing research funds in 6-month intervals. This has helped to create something of a stage-gating mechanism to incentivize progress on a timeline, and to keep the New Harvest team and the Principal Investigator engaged.

2. Regular, Scheduled, Updates

Abi updated us on an as-requested basis. As of November 2016, New Harvest began requesting weekly reports from all funded Research Fellows. They are presented at the weekly meeting described below. New Harvest has also begun to engage more with Principal Investigators, beginning in the application process.

3. A Weekly Forum For Scientific Discussion

Abi did not have a forum for sharing the unique research challenges she was facing in the laboratory. As of November 2016, New Harvest began holding weekly Slack meetings with all Research Fellows and New Harvest Staff to discuss progress from the previous week and any challenges, questions, and concerns moving forward. It has also been a venue to request connections to expertise within and beyond New Harvest's network. These meetings have proven to be an incredibly educational, helpful, and lively pacesetter for the researchers.

4. The New Harvest Research Director

Every Research Fellow has an on-site supervisor—but none of them (so far) are full-time committed to cultured meat research. In January 2017, we put out a job posting for a Research Director

to, among other duties, act as a remote supervisor for all of our Research Fellows. Kate, who begins in July, will be assisting the fellows on everything from day-to-day troubleshooting to redirecting the focus of a fellow's research project.

5. Face Time

New Harvest would only see Abi in person at conferences and at rare site visits to her laboratory. As of March 2017, New Harvest has begun to hold twice-yearly retreats for fellows to build community and offer input on how to improve the fellowship program. Beginning July, we will be creating a schedule for regular site visits by the Research Director.

6. Engaging Collaborative Laboratories

In an effort to share knowledge and techniques, Abi proposed to be a Visiting Scholar with the Pelling Lab in Ottawa. This proved to be an incredible opportunity to propagate interest in cultured meat research in scientific circles while learning new techniques from the people who developed them. New Harvest is currently developing the structure for a Visiting Scholar Program built into the Fellowship experience.

7. Starting A Research Group

Some of Abi's challenges came from being a sole researcher with this focus in her laboratory. New Harvest is reviewing new research proposals that place two or more researchers within the same laboratory. We think there might be a greater-than-the-sum-of-its-parts outcome from having collaborators working simultaneously in person.

Closing Thoughts

New Harvest has learned a lot since funding this first research project. We hope that with adequate feedback loops in place and regular check-ins, we can continue to improve the Fellowship program while conducting valuable research. While Abi did not reach the point of writing a thesis—she did generate a lot of data, and did work on several experiments worth sharing. We're excited to share these results in the coming weeks and months.

In addition to her research, Abi has been a vocal advocate for cultured meat research and gave numerous lectures and media interviews on the topic. Abi's public engagement helped generate interest in New Harvest and the field of cellular agriculture in the U.K. and Europe. Abi's supervisor at KCL, Lucy Di-Silvio, remains eager to help New Harvest and the field at large.

Abi is a scientist who cares deeply about food, farming and the broader global food system. She remains a champion for cellular agriculture and a more sustainable food system, and a friend of New Harvest. We're thrilled to have had her as our first ever Research Fellow. Although we're sad to see her leave the Fellowship program, we're excited for what lies ahead—for her, and for New Harvest.

Cellular Agriculture Abroad

An Interview with Yuki Hanyu, founder of Shojinmeat and Integriculture

We've been conducting casual interviews with researchers, entrepreneurs, New Harvest volunteers and donors, and other members of the cell ag community for our "Getting to Know" series since 2013. It was difficult to choose just one to highlight, but I was drawn to the one we did with Yuki Hanyu of Shojinmeat for a number of reasons.

Yuki founded Shojinmeat as a non-profit, DIY biohacker group in Japan whose unique style and spirit shines through in everything they do. I was super intrigued by their ingenious approach to fundraising (which includes selling mangas about cultured meat, and a graphic design service), the creativity in their vision of speculative cultured meat production facilities in space (complete with conceptual renderings), and their openness. The team has released videos and instructional blog posts documenting their at-home efforts at culturing animal muscle tissue. They also spun out a startup, Integriculture, as part of which Yuki is currently enrolled in the Singularity University accelerator program.



Shojinmeat is an inter-disciplinary collaborative project aimed at the development of cultured meat in Japan. The project consists of a number of volunteers working in a variety of "clusters" in both scientific and non-scientific subject areas, giving rise to the startup Integriculture Inc. Erin had the opportunity to chat with Yuki Hanyu, founder of Shojinmeat, about the history and vision behind the initiative. Yuki works full-time at Shojinmeat and Integriculture Inc., and lives just south of Tokyo, Japan.

"I've always been interested in 'dream science'—I'd already been thinking about cultured meat when I was around 8 years old"

Hi Yuki! Can you tell us a little bit about yourself?

My background is in Chemistry: organic and biological. My university was Oxford, at the time I was working on Nanotechnology, and after that I did my post-doc in Tohoku University, Japan. While I was there, I realized that I need to learn systems engineering and joined Toshiba. After that, I started my own thing, which included founding Shojinmeat Project. I actually don't feel like a founder but more like a convener, by raising the topic and finding more people who are interested. It's not yet an officially registered organization, but we are working to make it a legally defined entity.



*Team Shojin Meat after registering Integriculture!
Yuki is pictured 2nd from the right.*

How big is the team?

At the moment, the team is about 5-6 committed members and around 20 volunteers based in Japan. As you know, cultured meat spans many different topics. So there are people working by "clusters" defined by discipline or areas of interest.

How did you become interested in cultured meat?

I've always been interested in "dream science"—I'd already been thinking about cultured meat when I was around 8 years old, through reading science fiction mangas. I thought "in the future, I want to build spaceships or make cultured meat"—those kinds of wild ideas!

Wow! So do you identify as a futurist?

Yes. When I was in middle and high school I was always building sci-fi cities in SimCity and playing the typical "sci-fi stuff", and I haven't really grown up since then. In America, people watch Star Trek and get inspired by what they see on the show, and the same thing happens here.

Definitely. From your perspective in Japan, how is the public responding to Shojinmeat?

It's difficult to say, because we haven't approached all sectors of society. We generally reach more young people with a soft interest in science and pop culture (in the "geek/otakusphere"), and so far it's been overwhelmingly positive. The science people know about this stuff, and the pop culture people are somewhat familiar with it through creative works. The people we haven't approached are the elderly. Over 30% of the Japanese population is over 65 years old, and we can't really say definitive things until we've approached that demographic. As a start, we're approaching Buddhist organizations and asking what they think.

And is that where the word Shojin comes from? As a Buddhist concept?

It's from "shojin ryori"—the vegetarian cuisine for Zen. Shojin means devotion to path: nonviolence, middle way, harmony and all of those things. Our message is that the ongoing environmental destruction and all the unsustainable practices don't align with this path.



This conceptual image from the Shojinmeat website shows an imagined facility on Mars where humans culture meat as a source of protein.

Interesting. And how cool is your website (www.shojinmeat.com)?!

That's the work of one of our volunteers, who is in high school!

That's amazing! How do you find your volunteers?

We basically spun out of a place called Lab Café in Tokyo, and that's where people—mainly scientists—who aren't satisfied with just working in the lab every day. It's kind of a secret hideout for them. Many of them are hardware and software engineers, but some are biologists and chemists. I walked in and talked about my interest in cultured meat with some friends there. As we talked through, I met my co-founder and a few volunteers, and that started our team. We launched Shojinmeat Project in April 2015, and then founded Integriculture Inc. in October 2015.

How does Lab Café support itself?

It's supported by a patron, a man who said "there should be a place where future-oriented people can gather"—he was inspired by communities in Silicon Valley. Cafes where developers and programmers come together and come up with new ideas. TEDxUTokyo (University of Tokyo) and a number of startups and organisations are also based there.

Are you doing speaking engagements or any other kind of public promotion of Shojinmeat?

Only occasionally. We were on national television last fall and January, and we had our booth and session in Science Agora, a public science event organized by the Japanese Science and Technology Agency.

And I understand you went to the Cultured Beef conference in Maastricht this past year. How was that experience?

It was very inspiring and interesting to see how we place among the cultured meat community. It's a small community and there aren't many biohackers in cellular agriculture yet. I read about how small the community is and I saw that myself. But we are starting from there.

That's very true. And how did you find out about New Harvest?

I've known about New Harvest for a long time – around the time I started studying cultured meat in early 2014. We found NH some time in 2014, just by surfing the internet.



Anime style illustrations of the Shojinmeat research team

I understand you guys have a pretty unique approach to fundraising?

We provide scientific graphics (at www.scigra.com), the kind you see on the cover of a magazine like Scientific American. We use that revenue to fund Shojinmeat, so the project is pretty much self-funded. SCIGRA is also a science communication tool for Shojinmeat. We are trying to expand SCIGRA to raise more fund, and we might sell creative works like manga (which depicts cellular agriculture) too in the future. Integriculture Inc. is operating as a for-profit entity, while Shojinmeat Project operates as a non-profit.



A sample of cultured meat produced by Shojinmeat, shown being cooked and eaten.

What type of meat are you interested in starting with?

At the moment, cultured foie gras: duck liver.

Why foie gras?

We think it's not efficient to come up with a complete medium first, so we take basic medium and co-culture with liver cells, which produce various growth factors for muscle cells. We've already submitted a patent based on this concept.

Have you tasted it?

Not yet, for cultured foie gras. But we did taste cultured meat, which we posted on a video sharing site. The video combined with our fanzine booklet, created a bit of a buzz in January.

For sure! Would this foie gras product be sold on the Japanese market?

It's still early stage so we haven't decided on where it will be sold, but we're thinking of California too.

What do you envision in the next few years for cell ag and Shojinmeat in particular?

If the culture cost comes down, the public will see cellular agriculture as something more practical. For Shojinmeat, simply, we'd like to make cultured meat cheaper. We have a running setup that can grow 50g per batch with our low cost medium, but we still have to improve on prevention of contamination.

I see. Are you looking to grow the team?

More research staff would help. I'm the only full-time member, but we have a PhD that will be joining us full time soon, and another after that, but that will still be only 3 people.

What can NH do to help?

Help spread the word. Our viewpoints on cultured meat are quite different from others. I found at the cultured beef conference that many people are motivated by animal rights. But in Asia the perspective is different. That's understandable, because until now, most of the researchers in cultured meat are US and EU based, so the viewpoints of scientists in Asia haven't been included. Something New Harvest can help with is to and diversify the viewpoints that are included in the conversation.

Those are really great points. We'd like to diversify the basis of support in cell ag in general too. The conversation should be multi-dimensional and inclusive.

Yes, and selling our booklet at ComicCon-like events has been good for outreach too.

Was that strategic or just out of personal interest?

Both, actually. I do computer graphics and virtual reality as a hobby and I was distributing my work in Comic Market. There I thought "the people at Comic Market may be a good target audience for cultured meat." So we decided on selling our cultured meat booklet too.

That's smart!

People would photograph the book, and then post it on Twitter. And that raised awareness in Japan quite a bit. Japan is in quite a pressing position because we import most of our beef and price is a concern. And China has started importing a lot of meat from Australia. That and other factors have been causing the price of beef to jump in Japan.



Dr. Ikko of the Shojinmeat team cleans a CO2 incubator.

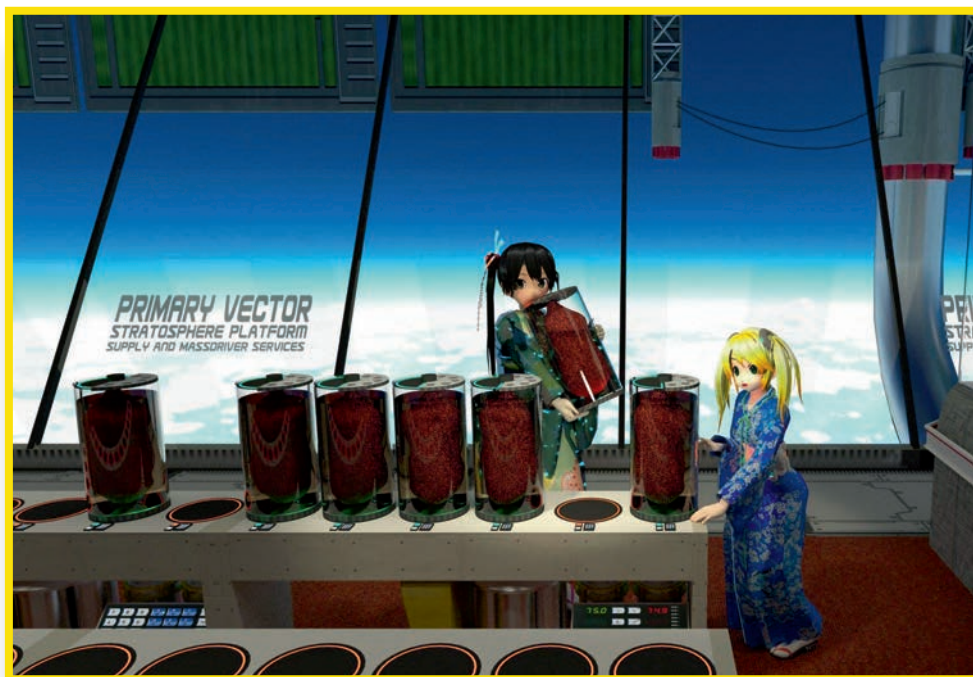
I see. In terms of the broader industry, what would you like to see?

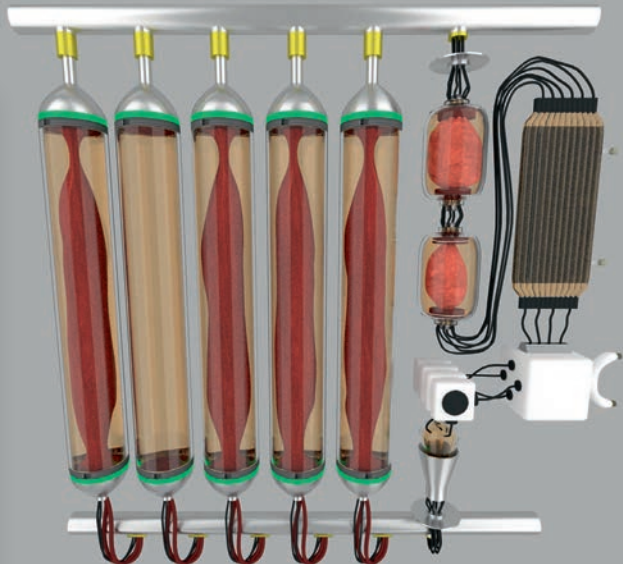
I'd say a patent pool. And for anyone who would like to support the Shojinmeat Project and has a need for scientific graphics, please visit SCIGRA. We take orders in English as well!

So the funds that are generated there directly support the Shojinmeat Project?

Yes, they'll go directly into research, like chemicals, lab rent, and things like that.

Wonderful. Thanks Yuki, all the best to you and the team!





What Do Farmers Think About Cellular Agriculture?

As cellular agriculture has the potential to change the way food and materials are produced and distributed in a potentially disruptive way, the questions of what current farmers and other workers in food production think about this new field of science, and how their work might be affected by its developments are crucial to consider.

Since 2015, the Nuffield Farm Scholarship has enabled two farmers to begin to explore the implications of cellular agriculture in their specific areas of expertise. We became familiar with Nuffield alumni Illtud Dunsford and Richard Fowler through the 2015 Cultured Beef Symposium in Maastricht and New Harvest 2016 conferences respectively, and crossed paths with Rebecca Seidel, a small dairy farmer in Pennsylvania, thanks to Twitter!

Farmers are a large, diverse group, and these three excerpts cannot speak for the entirety of global food producers—but we think that Illtud, Richard, and Rebecca's writings are a welcome and much-needed start for what we hope becomes a broader, more inclusive, ongoing conversation.

Illtud and Richard are two farmers from opposite sides of the globe (Illtud being from Wales, and Richard from New Zealand) who have conducted research on cellular agriculture as Nuffield Farm Scholars. The story behind the Nuffield Farming Scholarship program is that it was established by William Morris, the grandson of a farmer. After working as a bicycle repairman in Oxford, England, Morris began making newer bicycle models, and eventually started a motor car business.

Realizing in the then-early stages of the car industry that he should seek best practices, Morris travelled to Detroit to learn how reli-

able, lower cost cars were being produced in America. His model, the Morris Cowley, was able to compete with Henry Ford thanks to mass production principles learned in the United States. The Nuffield Foundation was established in 1943, and by 1947 its scope of objectives had widened to include agricultural advancement. The purpose of the Nuffield Farm Scholarship program is for scholars to "search out and bring back to farmers in the UK details of good and innovative agricultural husbandry, from different parts of the globe."

Illtud Dunsford comes from a centuries long line of farmers in Wales, and is an award-winning producer of artisanal meats as founder of Charcutier Ltd. His studies led him to the discovery of cellular agriculture at the 1st International Symposium on Cultured Meat at Maastricht University in 2015. Illtud's final report On Meat: niche production, value adding, ethics and its future within cellular agriculture documenting his world travels with the Nuffield program includes two chapters on cellular agriculture, which are excerpted below.

From Chapter 9.1: First International Symposium on Cultured Meat, Maastricht University

Prior to the conference I had given little thought to the actual process (of culturing meat); the sterile use of the terms "lab grown" and "synthetic" and the pervasive scientific nature of the language associated had clouded my perception of what the product was. That same language prevails, but the opportunities or the possibilities of the technology are plainly obvious. As a business that aims for whole carcass utilization, I have oft remarked that we are more in the business of waste management than anything else; utilizing our knowledge of process to maximize the potential profitability of each part of the animal, and giving the animal the respect of using

every single part. The quotation that struck it home for me most, derived from a piece written in 1931 by Winston Churchill. In looking to the future he imagined:

"We shall escape the absurdity of growing a whole chicken in order to eat the breast or wing, by growing these parts separately under a suitable medium."

—Winston Churchill, Fifty Years Hence, The Strand Magazine, December 1931*

Speaking at dinner with a Dutch meat scientist, it was clear that cultured meat in its basic form can be chemically analysed as being meat. However, meat as we think of it in a traditional sense, is a complex mixture of meat, fat, blood and a range of connective tissues. When speaking of cultured meat, I came to understand that in its inception it is purely the meat component, uncoloured and unflavoured. Though an industry in infancy, the realistic long term possibilities and its attractions are far ranging. Its effect on livestock production can be seen as both an opportunity and a threat.

There were two schools of thought – the first sought to utilize a donor herd, where sample biopsies would be taken from the animals to provide cells for growth.

Utilising every cell from a herd of around 40,000 pigs annually would provide sufficient resource to feed the whole world. The second system would utilize immortal cell lines, cells that would be initially extracted from livestock but would provide the basis for a population of cells based on that initial extraction. No future extraction would be needed, negating the need for any more livestock.

*<http://teachingamericanhistory.org/library/document/fifty-years-hence/>

The cautionary and preferred option would be the first. Though by no means a complete alternative to traditional agriculture, there are synergies and opportunities for smaller scale farmers to increase the quality of their work, by reducing their workload and increasing profitability. There is potential for smaller density livestock populations on farms which would result in higher animal welfare and would impact environmentally: lower land stocking density, reduce emissions, decrease soil erosion and reduce the impact on natural biodiversity of farmland. There would also be opportunities for the retention of the biodiversity of livestock breeds, with the onus on the production of cells as opposed to feed conversion, vigour and productivity; the use of more native and pedigree breeds would be as profitable as crossbreeds and hybrids.

From Chapter 11.3: New Harvest Conference, San Francisco

And so, I found myself on my very last Nuffield Farming trip headed to San Francisco. New Harvest were planning their first large scale conference and drawing on the hub of altruistic activity that emanates from the Bay bubble; there was no better place to host it. In her opening address Isha Datar, [Executive Director] of New Harvest, drew a comparison of Cellular Agriculture with the computer industry; though computers were invented in 1946, it took until 1962 for the field of Computer Science to be recognised, it took considerably longer for the advent of home computing, and longer yet for the smartphone revolution.

Earlier in the year I had been a panellist at the Grantham Centre for Sustainable Futures, Sheffield University, speaking on red meat and sustainability. A fellow panellist - the Business Development Manager for Quorn - had drawn equal comparison in food terms. Quorn is a cellular agriculture product, using fermenting technolo-

gy similar to the brewing industry. A mycoprotein is fermented and further processed to produce the meat substitute. This mycoprotein⁵⁸ component of Quorn was derived from fungi found in a compost heap in 1963. It then took over twenty years of development for the process to be accepted and approved by MAFF in 1985 as a food product. Quorn is now fully recognised and accepted as a food product, with unquestioned and clean brand values, and with sporting multi-Olympic gold medal winning runner Mo Farah as the face of their marketing campaigns.

Other examples of cellular agriculture that are now commonplace include the production of insulin for the bio-medicine industry and rennet for the cheese industry. Cellular agriculture it seems, is by no means a new field, but a field that is being re-packaged and reinvigorated by the re-appropriation of the developments within bio medicine and food science.

The field is growing immensely; panellists, delegates and exhibitors at the conference included a raft of companies who are looking at a range of products. They are predominantly developing products that are specifically animal derived:

[Geltor] (gelatine), Modern Meadow (leather), Muufri/Perfect Day (milk), Spiber (spider silk), Pembient (rhino horn) and Sothic (horseshoe crab blood) and span a range of applications, both food, clothing and also medicine.

Dubbed as the next era of fermentation, cultured meat it seems is still held as the holy grail of products with its complexity of production. Though some see cellular agriculture as the answer to the provision of agricultural product in response to factory farm-

ing, others, more pragmatic, see it as part of the answer to tackle the need to feed, clothe and heal the planet. There are considerable opportunities but also serious considerations to be taken with regards to the threat cellular agriculture could pose to traditional agriculture.

As one of the few farmers and meat processors in the audience, it was plainly obvious that there was little understanding of traditional agriculture in whichever form—intensive, extensive, holistic, sustainable et al. Though a negative, this can be corrected and can also provide opportunity.

An increase in cellular agricultural production will see a shift from land-based production to manufacture, but there is nothing stopping farmers diversifying and taking ownership of that process. We may yet develop the sustainable tools to feed both this world and the next.

Richard Fowler is a dairy farmer from Te Puke, New Zealand who received his Nuffield Scholarship in 2016. Richard focused his studies with the Nuffield program on the potential impacts of cellular agriculture on the agriculture sector in New Zealand, and included attending the first New Harvest conference in San Francisco in his travels around the world. Below is the Executive Summary from his report, "Will It Have Legs? An Investigation Into Synthetic Food and the Implications for NZ Agriculture":

Synthetic food (SF) is being touted as a revolution in food production that could replace animal products. While the industry is more bark than bite at the moment, it's rapidly gaining awareness and attracting significant funding by being portrayed as a solution to many of the global problems associated with conven-

tional agriculture. As the pressure intensifies on humanity to curb climate change, all options are being considered and, with a carbon footprint larger than the global transport sector, agriculture is well and truly in the spotlight. Agriculture has held relative impunity from climate mitigation strategies up until now but SF is bringing that into question by providing a potential alternative method of food production.

The environment is one of the key drivers behind SF but there are others as well. The drivers are being used as a platform to promote SF as the way of the future and leveraging off the growing disconnect between consumers and the farms that currently produce their food. It's too early to know if SF will actually compete at scale on a cost and quality basis but nevertheless, the messaging around SF is already having a negative impact on the perception of agriculture. Countries like NZ who rely heavily on agricultural exports are at risk of losing market share to SF as well as being tarred with the same 'industrial agriculture' brush as other countries and becoming what one journalist has described as the "Detroit of agriculture."

As with many emerging technologies though, things don't happen overnight and the devil is often in the detail. The NZ primary sector needs to resist the urge to take a stance against SF based on weak journalism and instead be part of an informed conversation. The first response from people a year ago, when discussing SF, was 'yuk, it will never take off because people want natural food'. Thankfully, the conversation is now shifting to 'what could happen if SF did take off and how do we approach this potentially disruptive technology?'. SF needs to be approached with an open mind and lots of questions rather than building a wall to defend our patch.

NZ Ag needs to get a better handle on how conventional food measures up against SF based on the ruler that tomorrow's consumer will use. Carbon emissions, soil conservation and animal welfare are some of the attributes that consumers will look for and this needs to become part of our marketing approach in the future.

In reality, conventional agriculture is more of a threat to the SF industry at the moment, not the other way around. SF consists of startup companies with products in the development phase and markets that are built on promises. This isn't a reason for us to rest on our laurels but instead a window of opportunity to get involved and have a say in how the SF industry evolves.

We can choose to be disrupted or help shape the future of food production by understanding the drivers behind SF and being part of the solution, not part of the problem.

A Dairy Farmer's Perspective on Cellular Agriculture

Rebecca Ruth Seidel is the dairy manager and cheesemaker of Wholesome Dairy Farms, a grazing operation in rural Pennsylvania. As a 4th generation dairy farmer, decade-long vegetarian, and former Penn State American Studies graduate student, she's interested in the intersection of animal ethics, scientific progress, and the American diet. Rebecca shares her perspective on cellular agriculture as a current dairy farmer in her first guest post for the New Harvest blog.

"Cellular agriculture should not be viewed as a threat by the agricultural community. Rather, it should be viewed as yet another tool to feed a growing population on a planet with limited resources."



The census of 1830s found that over 80% of the American population was employed as farmers. Today, less than 2% remain. The number of American farms and individuals employed as farm workers have been on a steady decline since the 1940s. Farmers who remain in the agricultural industry are fiercely protective of their occupation, their way of life. However, cellular agriculture should not be viewed as a threat by the agricultural community. Rather, it should be viewed as yet another tool to feed a growing population on a planet with limited resources.

The harm that has been done to the American farmer comes from a food system requiring quantity over quality, efficiency over ethics. At the same time, the vast majority of farmers have no control

over the price paid for their goods. The minimum cost of fluid milk is set by market and government force, while meat and poultry producers must take price offered by processors, often under contract while the animals are being raised. When the price of these commodities drop, industry news encourages producers to increase their output and lower their costs to make up for lost income.

Decades under this economic system have led to agricultural attrition: the strong (or lucky) survive, grow their businesses when prices stabilize and continue on until the next time the bottom falls out. The consolidation of production has not led to increased economic viability: the mean income of farmers and ranchers is around \$61,000 a year. Most of these farmers work long hours every day of the year.



To provide an example, between 2005 and 2015, the average American cow has been bred to produce 14% more milk, leading to a 16% increase in total milk production in the past decade. This would not seem extraordinary, except the number of dairy operations have decreased by 33% during the same interval. Less farms, more milk in a time when the total consumption of dairy products are decreasing.

While the per capita consumption of beef and pork have slightly declined over the past fifty years, the consumption of chicken has skyrocketed from just over 34 pounds of chicken to 108.6 pound of chicken per person, per year. Less farmers and increased demand have led to an industrialized system of food production in which animals are simply a living medium on which to grow meat. Cellular agriculture is the logical next step in this system, taking the animal out of the process and growing chicken breasts in a lab rather than on the chicken.

What we have now is an unsustainable system, which has been rendered inefficient by its drive to specialize. The egg industry, focused on high layer output, has no use for male chicks or unproductive hens, both of which are destroyed and discarded rather than being put back into the food chain. The dairy and beef industries work independently of one another, dairy bulls being sold for veal rather than raised for beef. Hogs, which were traditionally used to turn waste food into edible food, are fed a diet of cropped feeds and kept in confinement.

I believe adding cellular agriculture to this market system can only benefit producers by providing additional market competition and allocating traditionally raised animal proteins to a specialized product. We've already seen this with the growth of the organic

market and locavore movement. Consumers, demanding alternatively raised products, are willing to pay higher prices for pastured chickens, grass-fed beef, and woodland foraged pork. Less animals raised, a higher quality product, sold for a higher price.



Once farmers are able to earn a living producing less, environmental sustainability (rather than economic efficiency) could return to the agricultural system. Cows are solar powered animals, making food out of grass, water and sunlight, often from land that is unsuitable for crop production. In fact, the interaction of large ruminants is essential for the maintenance of some grassland biomes. Pigs and chickens can both function as part of a zero-waste food system, while the latter also acts as natural pest management for ticks, grubs, and other insects. Farmers can once again focus on animal husbandry rather than high production.

Our current food system will not be able to provide a growing population with the animal proteins it demands. At the same time, less farmers have been driven to create more food by an economic system that does not favor the producer.

It is a system that does not serve the farmer, the animal, or the environment. It is a system that should change.

Supporting cellular agriculture is an important step to moving the food system towards a sustainable future and, ultimately, sustaining the future of farmers as well.

An Inside Look at New Harvest '16

It's been a couple of weeks since New Harvest 2016—this is Erin's "NH True Hollywood story" of how it all went down*

We often joked in the office that there was something very wedding-like about it, with all the prep, nerves, and the actual day being a dreamy blur. So this is my attempt to describe what the world's first cellular agriculture conference was like, from my perspective*



*Although I had been volunteering remotely for over two years, joining the New Harvest team full time in May 2016 was a little bit like being thrown into the deep end and having to learn how to swim! I was figuring out my new role, a new city, and along with the rest of the team, scrambling a little bit to organize the New Harvest 2016 conference which would be coming up in a couple of months. As it was our first one, we were all understandably anxious and unsure as to how everything was going to turn out. But, as the many of you who were there experienced firsthand, it all came together pretty wonderfully in the end. The conference was a very special milestone for me because it kind of marked the “moment” where I felt like I was out of “volunteer mode” and finally in my groove as a fully-fledged member of the New Harvest team. And I thought it would be cool to share with our community a little bit of what it was like to plan and execute the conference behind the scenes, and that’s why I put together this little recap.

[Realtalk](#), a few months ago, we had our moments of wondering whether we could even fill 200 seats. But soon enough, we had to increase our ticket sales to make room for 250, and then again to an "absolute maximum" (ha!) of 280. In the end, 309 lucky people attended the world's first conference on cellular agriculture.

The conference took 6 months of planning—which I actually thought was "normal" until speaking with people who expressed their disbelief and awe that we pulled it off in so little time. Apparently planning for 1-2 years is more the norm?! Our New York team flew out together to San Francisco a week in advance. Plenty of time, we thought, for set up, maybe even a few meetings while we were on the west coast, the conference itself, of course, and lots of socializing.

Turns out that landing a week in advance was a little on the ambitious side, but we pulled it off. That week consisted of way too much pasta at the place next to the house we rented (the first couple of plates were great, but even the word "pasta" became nauseating after a few days of the same pesto), very little sleep—due to factors including our running around San Francisco grabbing random items like wood for the exhibition room displays from Home Depot; some very, very late nights printing at the 24-hour Kinko's; and the fact that our house was located right next to a busy club that would blast Mambo no. 5 and Bieber til 3am—and lots of blood, sweat, and tears putting the conference stage backdrop together.

On the day of, everything came together. Considering it was our first conference planned and executed all by ourselves, I was glad enough that we didn't burn anything down. But let's face it: it was awesome. It felt so good to have our vision of the conference play



out in reality. Standing on the stage and looking out at that sea of faces was pretty damn amazing. Because the cellular agriculture community is spread out all over the world, having opportunities to connect in "real life" are invaluable.

I've always loved how diverse our community is: students and scientists of so many different backgrounds (biologists, food scientists, engineers, doctors, veterinarians, to name just a few), academics from the social sciences, environmentalists, journalists, filmmakers, entrepreneurs, chefs, and people who are just excited about the possibilities that cellular agriculture has to offer. And knowing that people travelled from all across Canada and the U.S., and from as far away as Cambodia, Denmark, Israel, Ireland, Japan, and the U.K. was pretty incredible to say the least.

It's very difficult to pick out a highlight from New Harvest 2016. Seeing the Spiber Moon Parka was surreal. Not only did it look

cool, it represented that cellular agriculture can lead to tangible, sustainable, functional, and beautiful products that people get truly excited and inspired by. Seriously, a parka made out of synthetic spider silk is kind of a big deal!



Having Soylent sponsor and provide samples for us was such an honor. A half-bottle of Soylent sustained me up until lunchtime (and deliciously, I might add. As Meera pointed out to me while we were frantically gulping it down backstage, the new iteration tastes kind of like Biscoff cookies), and upon my return home to New York I needed another hit. I immediately ordered a case.

Since joining New Harvest full time in May I've been lucky enough to spend some time with the amazing team at Forelight, who also exhibited at NH16. Why is everyone at Forelight so cool? They're making sustainable dyes for the food & beverage, cosmetic, health, and animal feed industries out of algae and are legit some of the smartest and kindest people I've gotten to know through cellular agriculture. When you get to see that people this brilliant are working in the same industry as you, you know you're doing something right.



The community that is building around cellular agriculture is really quite amazing. We may be spread out across the world, but faces are becoming familiar and the connections that are being made are very real. One of my only regrets about our week in San Francisco is that we were only there for a week! It flew by, and wasn't nearly enough for all the social time that we'd hoped for. It HURT to have to decline on things due to a lack of time. We'd hoped for a big post-conference afterparty of some kind (we even booked our place on Union Street in part because it was advertised as a "great space for parties") but that turned out just to be a nice idea. By the evening of the 13th we were absolutely wiped.

That night we literally laid on the floor and just marinated in the post-conference glow together while David Zilber (sous chef at noma, who moderated a panel at NH16 and who we are blessed enough to call a friend) cooked us one of the most unbelievable meals of our lives. That guy turned a head of cabbage (among other ingredients) into a life changing experience for us. Thank you David, I still cant believe it was even real.



Another regret of mine is that in our rush to take our big group photo, we weren't able to adequately thank Morgan Catalina, without whom the conference would NOT have been possible. Morgan was 100% the unsung hero of New Harvest 2016. She was with us from the inception of the very idea of holding the conference, through every single minute detail during the planning process, the crazy awesomeness of the day of, and the wrap-up—all while working full time at SXSW. Not only is she the reason why everything went as great as it did, she was an absolute blast to work with. *THANK YOU MORGAN!!!*

“What New Harvest Means To Me”

While those who give to New Harvest provide the financial means for the research that we fund, conducting the science itself is a team effort, carried out by New Harvest's network of scientific pioneers from various backgrounds working together on the challenges of culturing meat, piece by piece. For many of the scientists in our community, dedicating a stage (or more) of their careers to the advancement of cellular agriculture was a dream that could only have been made possible because of New Harvest's funding activities. For others, guidance provided by a member of staff or a Research Fellow served as either a catalyst or as support for a cell-ag related project. As we saw the numbers of these scientists and projects grow, we asked if they would describe and share the impact that this has had for them and their work.

"I have been cultivating turkey satellite cells since 1993. I arguably have more first-hand experience than anyone else in the world cultivating avian muscle cells. I routinely teach an animal cell culture class (where I teach avian muscle cell culture), and there is always someone in my lab cultivating muscle cells.

I have been thinking about the problem [of cultured meat] for a very long time, and I have engaged engineering professors at NCSU to discuss scaffolds; the issue is that USDA competitive grants are not going to fund in vitro meat production since they only fund mechanistic hypothesis driven research, and the poultry industry at this point is not interested in funding research on biomanufactured meat. *The only place that would even consider funding the work is New Harvest.*

I have wanted to do this project for almost 20 years. I am very excited about the possibilities."

—Paul Mozdziak,
Professor,
Prestage Department of Poultry Science
at North Carolina State University

"As a volunteer, employee and researcher of this organization over the past three years, I can attest to the impact New Harvest has made on the cellular agriculture movement. Never have I been involved with a group of people so dedicated and passionate about making this technology a tangible reality.

After I graduated college I desperately wanted to work on cultured meat research, but there were no places to do so. The handful of existing companies were hiring senior level scientists and academic tissue engineering programs only supported medical research. Then came the New Harvest Cultured Tissue Fellowship! Thanks to this support, I have the scientific network and resources to begin my career in cultured meat development while obtaining a Ph.D. from Tufts University. Donating to New Harvest means putting money directly into foundational research for safe, sustain able and humane food. If you care about our environment, food security, public health, and/or animal welfare—You have every reason to donate today!"

—Natalie Rubio,
PhD candidate,
Tufts University

"Cellular agriculture is a very new technology, and as such it absolutely requires cooperation between public and private sectors. New Harvest is driving forward the public research that needs to be done in order to make this field not just a reality, but a reality with equal access for all.

I wouldn't have gotten into the field of cellular agriculture if not for New Harvest's resources and guidance, and for that I'm extremely thankful. I can't think of a more important cause to donate to."

—Michael Selden,
CEO and Co-Founder of Finless Foods

"If it wasn't for New Harvest, I would probably be in vet school right now. I know, I know—that sounds like a bad thing, right? For many, giving up the opportunity of a lifetime to spend their days in a lab sounds crazy. Until you consider why I was going to be a veterinarian in the first place...

Ever since I can remember, I have loved animals. ALL animals. And early on, I decided I wanted to devote my life to make this world better for them, humans included! So veterinary medicine was an obvious route. I hoped to help thousands of animals by working as a farm animal veterinarian, promoting pain management, enrichment, and more humane care. But I soon realized that the type of impact cellular agriculture could have on this world would be absolutely colossal! If I was ever lucky enough to get involved, my efforts could prevent the suffering of countless animals by sparing them their own existence. So! With this new revelation, I decided to shift gears and contacted New Harvest.

New Harvest is the reason I am here today. They are the reason why my research is even possible. New Harvest has provided me with funding, connected me with expert scientists, flown me around the world to spread the word, and most importantly, provided undying moral support and guidance throughout the entire process. So here I am. 7 months in, and I'm growing the first ever chicken and turkey meat in the lab—all because of New Harvest! They gave me a chance to pursue my dreams of making this world a better place, and I know that as this field grows, New Harvest will make those dreams come true!"

—Marie Gibbons,
North Carolina State University

"After learning about the devastating effects that the animal agriculture industry has on climate change environmental destruction, in vitro meat became my dream in 2010. For the past six years I've tried navigating through the research funding world with this hope in mind. Unfortunately, because there is no obvious funding agency tailored to the study of in vitro meat, it's been very tough to advance this field. That was the case until I met New Harvest! Their team has done an incredible job providing guidance and opportunities to advance my research.

One of New Harvest's greatest strengths is that it's run on donations from people who fund the change they want to see in world. With support from donors, we can protect all life on earth by making cellular agriculture a reality. I'm so proud to be part of this team and I couldn't be doing what I love without New Harvest! Together we're making the world a better place."

—Jess Krieger,
Kent State University

"New Harvest have given me the most amazing opportunity to really disrupt the industrial farming system. The last year of my project has been such an epic journey, presenting opportunities and challenges I could never before have dreamed.

I am so thankful for the support I have received from New Harvest, and the unwavering enthusiasm and drive they proceed with to create the fundamental research building blocks of the field of cellular agriculture is inspiring.

However, as New-Harvest is a non-profit, this work can only happen through donations. Any support they can receive will be greatly appreciated and put to good use!"

–Abi Glencross,
former PhD candidate,
King's College London

"When I was offered the opportunity to pursue a research project as part of my undergraduate degree, I decided to do it in cellular agriculture. However, the Faculty of Land and Food Systems at UBC didn't have labs dedicated to the development of 3D tissues.

My [current] supervisor took a shot on me, allowing me to use his lab as long as I was able to find a collaborator with knowledge in tissue engineering and cellular agriculture. I had the privilege of connecting with Daan Luining and New Harvest, who offered to assist me. I can't thank them enough for providing advice, proof-reading my work and overall, for inspiring me. I believe that New Harvest will be able to revolutionize agriculture by providing a more ethical and sustainable way of meat production. The planet depends on new alternatives, especially as climate change brings us closer and closer to the point of no return. Thanks to generous donors, New Harvest can continue to do this revolutionary work, and nonetheless assist those who share a similar vision."

–Santiago Campuzano,
University of British Columbia

Why I Give To New Harvest

The importance of individual donors' generosity to New Harvest's survival (and growth!) simply cannot be overstated. Our organization is only able to exist and achieve all that has been described in this reader because regular individuals keep showing us, through their generous financial support, that the possibility of meat without animals is something worth striving for.

Over the past decade, we've been supported by a community of 570 (at the time of writing) people who are motivated by a variety of factors to give what they can. In December 2016, we began collecting "blurbs" from our donors stating why supporting this early stage research through New Harvest matters to them. Here they are, in their own words.

"I want a world where animals aren't raised and killed for food. I donate to New Harvest because they're playing an essential role in making my desire a reality. New Harvest continually finds big ways to advance cellular agriculture, a field I considered science fiction until recently."

—Jason Ketola

"New Harvest is working to build a better world; one in which we can provide protein for our ever-growing population in a more efficient, sustainable, and humane way. I'm grateful for its efforts!"

—Paul Shapiro

"I think it's really exciting that New Harvest is funding a lot of the basic research that needs to happen, otherwise this won't go anywhere... I have a pervading thesis that it's easier to change technology than it is to change people. There's lots of people who talk about wanting to reduce meat consumption, and that kind of thing. But I think that we'll be able to get cellular agriculture to the place

where we can create lab grown meat cheaper and more efficiently and better than any kind of animal grown meat, faster than we can shift people off eating meat."

–Joshua March

"In 2013 I watched in awe the unveiling of the first cultured meat burger in London. In 2016 I actively researched the progress of cultured meat, at which point I came across New Harvest. I was astonished to find a dedicated group of people with an amazing vision: to transform our meat consumption. I am so happy to donate because I love their dedication to changing the way we produce meat. Instantly, a world without animal slaughter seemed so much nearer. That's why I donate."

–Katharina Eist

"I believe New Harvest is doing work that is absolutely vital to the future of our booming world population. New Harvest's efforts to completely rethink how animal agriculture works is an inspiration, as it is only through innovations like cellular agriculture that we'll be able to solve our current environmental, health, and ethical challenges."

–David Leibowitz

"New Harvest has been foundational in forging the field of cellular agriculture and driving it forward. It's amazing the milestones in this field that they have achieved and facilitated, all the while operating with minimal funding. As someone who is concerned with animal welfare and who believes in the power of technology to transform our world for the better, supporting New Harvest has been, continues to be and will be by far and away the most effective and meaningful charitable giving I have ever done."

–Tracey Lall

"I work as a school secretary in northeast Ohio, and I live modestly. I have been donating \$30 a month to New Harvest for over a year now. The fact that \$30 is a lot to me, and the fact that I would cut other lifestyle choices before I cut this donation, should tell you how passionate and hopeful I am about the possibilities ahead with New Harvest. I saw, about 7 years ago, an insanely horrific pig slaughterhouse video. I could not unsee it, no matter how hard I tried. It changed me forever. Up to that day, my favorite sandwich was a BLT. After that video I began researching factory farming. It's been 7 years since I have had a BLT. New Harvest makes me sleep a little better each night, knowing that smart, compassionate individuals are working tirelessly towards a day when that horrific video I saw will be a part of history and not a part of present day. Like slavery, it has no place in a civilized and kind world. Thank you, New Harvest. I only wish I could give more."

–Susie Thomas

"I make regular donations to New Harvest because they are fighting what I consider to be the most important fight in the name of both animal welfare and animal rights... putting an end to factory farming, the worlds greatest cause of animal suffering, with practical, realistic and applicable solutions. This work is phenomenal and comes with the ability to positively impact the environment and antibiotic resistance on a global scale that I cannot even imagine!"

–Rachel Graham

"I found out about New Harvest from, and was inspired to contribute by, my granddaughter Marie Gibbons who works with the cultured meat program at NC State University. My contribution was given as much in support of the program as it was out of love for my granddaughter. I understand that the technological and financial hurdles confronting the development of cultured meat

are daunting, but the ultimate success of this program will literally change the world."

–Ron Barbee

"I donate to New Harvest because their work is critical to advancing cellular agriculture. Whether it's jump-starting companies, funding research, or building up the scientific community, New Harvest is at the forefront of creating a healthier and more humane food system."

–Anonymous

"I love supporting this idea. It takes a completely different approach to lowering animal suffering, one that could have a much stronger impact in the future compared to, for example, standard vegan activism. Being a vegan myself, I understand that this might be a controversial topic, but regardless of opinions of individuals - once your mission fulfills itself and we will grow tissue in a lab, there will be no suffering involved, therefore the mission will be accomplished from a vegan perspective too."

–Lukas Cech

"The research New Harvest funds has the potential to transform the global food system by making animal products animal-free and therefore environmentally sustainable and completely humane. It's hard to argue that there's a more important goal in the world. The world needs New Harvest, and New Harvest needs the world to support its work."

–Trent Eady

Media Highlights

Getting press in cell ag is a bit of a double edged sword. It's not particularly difficult to get mentions or an occasional headline, but getting a high quality story that doesn't butcher a quote and manages to resist the temptation of a wildly optimistic headline or the easy trap of an outlandish sci-fi headline ("Frankenmeat" anyone?) is another story. We chose to highlight these three articles because each one was thoroughly researched, science-focused or otherwise grounded in reality, or because it mentioned aspects of our work that we think are deserving of the spotlight, whether that's our partnership with a world renowned poultry expert (hint: it's Dr. Paul) who had dreamed of culturing meat for decades, or our open source methodology. In the case of the Science magazine article, the question of how regulatory bodies might treat cellular agriculture food products is such a "fan favorite" that we felt it was a must to include it. We hope you enjoy them as much as we did!

Meet The Test-Tube Turkey That Costs \$34,000

by Andrew Rosenblum

This Thanksgiving, Paul Mozdziak will be giving thanks that people are finally paying attention to his big idea.

He wants to grow turkey meat in 5,000-gallon tanks.

Mozdziak is an expert in growing avian muscle cells in a lab flask. That obscure corner of research recently landed the North Carolina State University professor of poultry science at the cutting-edge of "cellular agriculture," or the idea that animal protein could be manufactured in bioreactors rather than by animals.

The technology, also known as in vitro meat cultivation, may sound strange. But it has been drawing a following of environmentalists, animal-rights activists, and investors who think meat can be made by biotech companies rather than on farms.

"Years from now, when people are [in] the grocery store trying to decide if they want to buy traditional versus cultivated meat, I am 100 percent sure that cultured meat is going to be just as cheap, if not cheaper," says Mozdziak.

The idea of cultured meat took flight in 2013, when Dutch scientist Mark J. Post went on British TV and cooked and bit into the first lab-grown hamburger. The experiment cost more than \$300,000 and was paid for by Google founder Sergey Brin.

Proponents say in vitro meat could reduce reliance on farm animals and save resources. This summer, Mozdziak was a featured panelist at a conference put on by New Harvest, a foundation that promotes "animal products without animals." The San Francisco event featured innovators presenting their versions of lab-grown beef, gelatin, egg whites, and milk.

Mozdziak's research begins with a pencil-eraser-size biopsy of a turkey breast. Then the job is to isolate stem cells known as satellite cells, which multiply and fuse to build up existing muscle fibers. By manipulating these prolific cells in a warm broth of glucose and amino acids, Mozdziak essentially tricks them into behaving as if they are still inside a turkey.

In theory, the growth potential is enormous. Assuming unlimited nutrients and room to grow, a single satellite cell can undergo 75 generations of division during three months. That means one cell could turn into enough muscle to manufacture over 20 trillion turkey nuggets. Surveys suggest about half of vegetarians would eat meat if it came from a lab.

"Muscle to me is the most fascinating tissue and cell type that exists," says Mozdziak, who earned his PhD studying satellite cells. "Let's just put it this way—I find a lot of beauty in turkeys."

Lab-grown meat is still far from being economical. In Mozdziak's lab, his team grows cells as a thin layer inside plastic flasks. If the cells become too thick, nutrients can't get in. Growing a turkey-size amount of white meat this way would require about 11,340 flasks and about \$34,000 worth of growth serum.

Hultz Smith, a scientist charged with studying long-term innovation for Tyson Foods, the Arkansas food processing giant, says his company is keeping an eye on cultured meat, but isn't yet ready to invest. He thinks scientists are still far away from making a dent in the \$675 billion global meat trade.

At the New Harvest conference, Smith asked the audience of cultured meat impresarios how many believed they were ready now to scale up their research into a real business. "Crickets," says Smith. "Not one hand raised."

One company, Memphis Meats, has turned cattle stem cells into ground beef, but so far at a cost of \$18,000 a pound. Another, Modern Meadow, dropped its highly publicized plans for laboratory beef chips and instead is working on synthesizing leather, a far more valuable commodity.

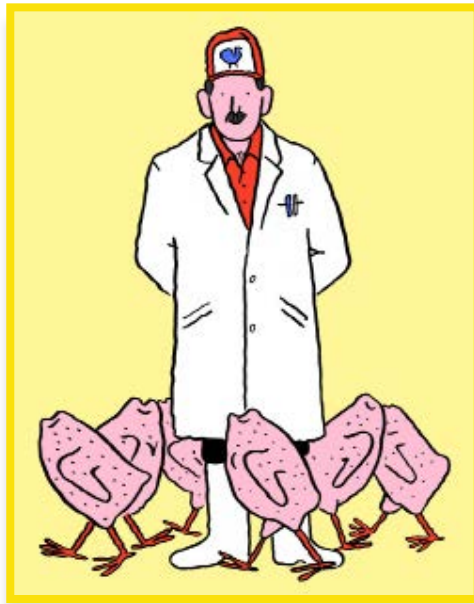


Illustration by Gwendal Le Bec

Make Your Own Meat With Open-Source Cells

No Animals Necessary

by Elizabeth Devitt

IMAGINE producing meat at home without killing animals. With a few cells and a keg, the process could be no more complicated than brewing your own beer or pickling vegetables. That's the vision of Isha Datar, the CEO of New Harvest, a non-profit organisation aiming to create everything from burgers to silk from cell cultures. "It's like designing a new universe," she told Hello Tomorrow, an event that brought together technology entrepreneurs in Paris last year.

Cultured meat isn't a new idea but it has largely focused on mass-producing beef and pork. In 2013, the first tasting of a lab-grown burger in London grabbed headlines, but the showpiece cost "300,000 and took a year to create. The taste of the burger was described as intense," close to meat but not as juicy." Growing large quantities of meat from cells in a sustainable way is still far off. As Datar says, "there are so many breakthroughs required."

One of the biggest problems is producing a thick enough piece of meat. The hamburger created for the press event was made by combining several small lab-grown pieces. Since meat is predominantly made of muscle, the process currently involves harvesting muscle stem cells from an animal's body. These are the self-renewing cells that are activated after an injury to repair the damage. They are then coaxed to multiply in the lab by mimicking the job of blood vessels, feeding them with nutrients and oxygen. Although scaffolds are typically used, they struggle to supply every cell as the tissue gets thicker.

Some types of meat may be easier to scale up than others, though. Paul Mozdziak from North Carolina State University and his colleagues, who are working on producing cultured turkey meat,

have found that avian muscle cells may not need a scaffold to grow. Instead, they could be cultured in a vessel like a keg or bioreactor, which would allow larger samples to form. Avian cells seem to be able to adjust to different environments more easily than bovine cells, says Datar, so they would be more conducive to home culturing.

Last year, New Harvest started funding Mozdziak's turkey-meat work. Although many enthusiasts of lab-grown meat are driven by animal welfare, Mozdziak is simply motivated to advance food science. He is excited to get to the stage where he has edible pieces of meat to sample. "I'm curious about what it will taste like and how tender it will be," he says. "It should have almost the same texture as existing meat but we don't know for sure."

Taste is a complicated issue for researchers trying to engineer meat because all different kinds of tissue contribute to flavour. Meat isn't pure muscle: its fat content is responsible for much of its culinary appeal. But Mozdziak and his team found that certain turkey cell cultures could be coaxed to form fat along with muscle when subjected to specific conditions. And the process could be tweaked to combine the muscle and fat into a desired consistency. However, it will probably be easier to replicate the texture of a nugget than to apply the technique to try to replicate a tender prime fillet of beef. "Taste is a complicated issue because all different kinds of tissue contribute to the flavour" Experimentation will be key. But the first hurdle often faced by enthusiasts is obtaining cells to start the process. At the moment, muscle stem cells are most easily obtained from fresh meat at a slaughterhouse or from live animals – preferably young ones since their stem cells are more plentiful. But harvesting them is hard work.

Datar hopes to change that by making cell lines available for order from lab supply catalogues or by linking up researchers so those with cultures can share them with others, much as people share sourdough starters to make bread. For Datar, "it would be like open-source software. The cells are the code."

Mozdziak thinks that a scaled-up cultured meat prototype could be available in three to five years, but would take longer to appear on supermarket shelves or to join the ranks of DIY food. But once the process is refined, meat as we know it can be reinvented, for example, by creating novel flavours and consistencies.

"It's absolutely possible to tweak taste and texture," says Mozdziak.



As Lab-Grown Meat And Milk Inch Closer To U.s. Market, Industry Wonders Who Will Regulate?

by Sandrine Ceurstemont

The quest for artificial meat inches forward—the company Memphis Meats announced today it has developed chicken and duck meat from cultured cells of each bird, producing "clean poultry." The firm provided few details, although participants at a tasting reportedly said the chicken tasted like, well, chicken. Below is a repost of a story originally published 23 August 2016 on some of the regulatory challenges and questions facing Memphis Meats and other companies pursuing artificial meats.

The first hamburger cooked with labmade meat didn't get rave reviews for taste. But the test tube burger, rolled out to the press in 2013, has helped put a spotlight on the question of how the U.S. government will regulate the emerging field of cellular agriculture, which uses biotechnology instead of animals to make products such as meat, milk, and egg whites.

So far, none of these synthetic foods has reached the marketplace. But a handful of startup companies in the United States and elsewhere are trying to scale up production. In the San Francisco Bay area in California, entrepreneurs at Memphis Meats hope to have their cell-cultured meatballs, hot dogs, and sausages on store shelves in about 5 years, and those at Perfect Day are targeting the end of 2017 to distribute cow-free dairy products. It's not clear, however, which government agencies would oversee this potential new food supply.

Historically, the U.S. Department of Agriculture (USDA) regulates meat, poultry, and eggs, whereas the Food and Drug Administration (FDA) oversees safety and security for food additives. FDA also approves so-called biologics, which include products made from

human tissues, blood, and cells, and gene therapy techniques. But emerging biotechnologies may blur those lines of oversight, because some of the new foods don't fit neatly into existing regulatory definitions. "Cellular culture raises a lot of questions," says Isha Datar, CEO of New Harvest, a New York City-based nonprofit founded to support this nascent industry.

To help provide answers, the White House last year launched an initiative to review and overhaul how U.S. agencies regulate agricultural biotechnology. And the National Academies of Sciences, Engineering, and Medicine in Washington, D.C., is working on a broader study of future biotechnology developments and regulation, with a report slated for release at the end of this year.

(Editor's Note: The report was released on March 9, 2017)

In the meantime, industry leaders are thinking about how their potential lab-based foods might be handled by regulators. One approach, they tell ScienceInsider, is to show that their product is similar to an existing product that testing has already shown to pose no hazards. "Most food regulation is about aligning new products with something that's already recognized as safe," Datar notes. That's the approach already taken by companies that use microbes and other biotechnologies to produce enzymes and proteins that are added to foods, notes Vincent Sewalt, senior director, product stewardship and regulatory, for DuPont Industrial Biosciences, based in Palo Alto, California.

For example, yeast can be used to produce specific amylases, which are enzymes added to baked goods to prolong freshness. Such additives require premarket approval from FDA "unless you can demon-

strate they are substances generally recognized as safe," Sewalt says. To meet that standard—known in the industry as GRAS—companies start by selecting microbial strains that are known to be nontoxigenic and nonpathogenic, then use those strains to produce their products. "And that can be safely done as long as you've selected a safe strain and demonstrated that safety through repeated toxicology studies," Sewalt says.

That strategy might also work for companies experimenting with using engineered yeast to produce single proteins to create egg whites, without cracking open a chicken's egg. In this case, egg white proteins are already considered to be a GRAS ingredient.

The same scenario might also work for Perfect Day, the startup that's using yeast to make milk proteins, and then adding other ingredients to create a cow-free "milk." Those milk proteins, caseins and whey, are already recognized as safe because they're identical to the milk proteins we get from cows, says Datar, also a founder of the company.

The product can't legally be called milk, however, because FDA has standards of identity that specifically define milk as lacteal secretions from a cow. "That definition completely leaves out any kind of beverage produced by fermentation or other tools of molecular biology," says Phillip Tong, former director of the Dairy Products Technology Center and professor emeritus at California Polytechnic State University, San Luis Obispo. "When these definitions were promulgated, nobody ever thought we'd be able to do something like this," he adds.

Meaty complications

The regulatory situation gets more complicated with cell-cultured meat, in which cells taken from animal muscle are grown on special scaffolds until they form enough tissue strands (about 20,000) to make a meatball or hamburger. It is not quite animal, not exactly a food additive—yet intended as food.

"It's uncharted territory," says Nicole Negowetti, policy director for the Good Food Institute, a Washington, D.C., nonprofit that supports cultured and plant-based food alternatives. For example, "from my understanding, the USDA regulations are based on food from animal slaughter, so [they don't] make sense for these products," she says.

Although cellular agriculture advocates tend to dwell on the process—because they say it could lead to safer, more humane, and more sustainable food production—FDA looks only at the final product. So, whether the end product is genetically modified corn, soybean, or maybe meat, Negowetti says the product should be regulated by FDA if it is meant to be a food.

But meat from cell cultures could also fall under FDA oversight for drug manufacturing, she notes. Because FDA defines a drug as something that includes human cells, tissues, and tissue-based products, it might not be so much of a stretch to say animal tissue could be included in that definition, too, she adds.

There also could be arguments made for regulating cell-cultured meat under FDA's New Animal Drug Application process. Under this scheme, the agency regulates drugs given to animals or added to their food. So if companies manipulate meat cultures to improve the flavor, fat content, or other qualities, that could be considered the same as giving a drug to an animal.

Safety advantages?

Although biotechnology may make it harder to define new food products, it could also facilitate more precise safety measures, DuPont's Sewalt says. For instance, he says that as genome sequencing becomes faster, so could the process of figuring out whether gene insertions or deletions in new organisms pose health risks or other concerns. There's also the possibility of explicitly designing in safety, such as by engineering egg white proteins so they don't trigger allergic reactions. And, in the future, the potential to insert barcodes in genes and the development of in-line ID kits, that recognize specific strains of cell lines, could make it easier to verify new organisms and their protein products, and track products through supply chains.

For the moment, however, which government agencies will oversee these changes remains unclear. As biotech creates more overlap among regulatory systems, Datar suggests it would be ideal to create a single regulatory agency. "Right now," she says, "our system is set up in a way that promotes imitation as opposed to innovation."

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