



# GOOD FOOD IS GOOD BUSINESS

Opportunities driving the future of affordable nutrition

### **About This Report**

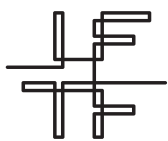
“Good Food Is Good Business” was developed by the Institute for the Future (IFF) and commissioned by the Bill & Melinda Gates Foundation. It forecasts future forces that will drive private-sector business opportunities to create more affordable, accessible, appealing, and nutritious foods for lower-income consumers over the next decade. The report is aimed at four stakeholder groups: national and regional food and beverage companies, multinational food and beverage companies, innovators, and input suppliers to the industry. For more information, visit [www.iff.org/goodfoodisgoodbusiness](http://www.iff.org/goodfoodisgoodbusiness).

### **Institute for the Future**

Institute for the Future (IFF) is celebrating its 50th anniversary as the world’s leading non-profit strategic futures organization. The core of our work is identifying emerging discontinuities that will transform global society and the global marketplace. We provide organizations with insights into business strategy, design process, innovation, and social dilemmas. Our research spans a broad territory of deeply transformative trends, from health and health care to technology, the workplace, and human identity. IFF strives to comply with fair-use standards and publish only materials in the public domain under the Creative Commons 4.0 International License (CC BY-NC-ND 4.0). IFF is based in Palo Alto, California. For more, visit [www.iff.org](http://www.iff.org).

### **The Bill & Melinda Gates Foundation**

Guided by the belief that every life has equal value, the Bill & Melinda Gates Foundation works to help all people lead healthy, productive lives. In developing countries, it focuses on improving people’s health with vaccines and other life-saving tools and giving them the chance to lift themselves out of hunger and extreme poverty. In the United States, it seeks to significantly improve education so that all young people have the opportunity to reach their full potential. Based in Seattle, Washington, the foundation is led by CEO Dr. Susan Desmond-Hellmann and Co-chair William H. Gates Sr., under the direction of Bill and Melinda Gates and Warren Buffett.



**50**  
YEARS

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# Executive Summary

The world needs a food system that works for everyone. To put it simply, today's affordable foods are not always nutritious, and today's nutritious foods are not always affordable.

Low- and middle-income countries rarely show up on the radar of large multinational food companies. When regional and local companies see these markets, affordable nutrition is rarely the focus of their innovation, R&D, or business development strategies. For those few companies who develop nutritious foods for low- and middle-income markets and survive, their impact remains limited and their scale small. Providing healthier, more nutritious, and more affordable foods to lower-income consumers is therefore a grand challenge, shouldered mostly by food aid organizations along with some private-sector actors.

Until now.

While the challenge of nourishing the world is formidable, we believe significant opportunity for innovation exists within our market-based food system to improve the health of nutritionally vulnerable populations. Over the next decade, a confluence of rapidly advancing technologies will allow us to reengineer the food system to benefit humanity while at the same time boosting the bottom line for food industry corporations.

This new, equitable food landscape will emerge from the opening of the multi-trillion-dollar food industry to new and unexpected sources of innovation. Emerging technologies like artificial intelligence and synthetic biology will meld with well-established strategies, and scientific breakthroughs will intersect with traditional food wisdom to lower costs and enable food companies to develop novel products that are both nutritious and affordable. Market risk will decline as the consumer base grows. Lower-income people will become empowered consumers wielding significant aggregate purchasing power.

In this report, we explore five zones of technological innovation that will spark an affordable nutrition revolution, finally making it possible for food companies to do well and drive market share—while doing good.

## HOW TO USE THIS REPORT

- › **Calibrate your understanding of the problems** related to affordable nutrition for lower-income consumers.
- › **Immerse yourself in the opportunity zones** and their related forecasts to imagine possibilities for the food system on a ten-year time horizon.
- › **Explore the insights for affordable nutrition** to think systematically about changing the landscape of nutritious foods.
- › **Engage with the design principles** presented in the conclusion to experiment with your own ideas for how to create innovations for affordable nutrition.



### AI COLLABORATION

Toward improved products and better-educated consumers

AI will offer new tools to help multinational and local companies deepen their understanding of consumers' needs and aspirations. Algorithmic persuasion will also lead consumers in lower-income (and all) markets toward healthier and more economical consumption habits.



### TRADITIONAL WISDOM

Toward reincorporating time-honored health practices and ingredients

Thousands of years of human intuition about the roles and benefits of food ingredients and preparation techniques will be amplified and reintegrated into new food products. This traditional knowledge will be open, accessible, and actionable by any consumer or producer, anywhere in the world.



### MICROBIOTA MANAGEMENT

Toward microbe-friendly diets for optimum health outcomes

The expanding notion of human health—and the interconnected relationship between our diet, well-being, and microbiome—will deepen and open up new opportunities to design food that resists spoilage, tastes better, and targets the nourishment of both bodies and microbes.



### CELLULAR AGRICULTURE

Toward reinventing animal-based products at the cellular level

Advances in synthetic biology will be applied to food production, enabling the creation of agricultural products through cell cultures that may cheaply and sustainably scale nutritious foods in growing market categories while avoiding the negative environmental impacts of animal agriculture.



### PROGRAMMABLE ASSETS

Toward frictionless transporting and transacting

Food companies will be able to leverage cryptocoupons, smart contracts, and utility tokens managed on blockchains to track food cheaply as it moves from farms to tables. The same systems will optimize organizational functions, enhance food safety at lower costs, and incentivize the consumption of a nutritious food basket.

As synergies between these forces and future opportunities are established, food companies will be able to meaningfully tap into lower-income markets. As you'll see in this report, it's good business to create affordable and nutritious food for those who need it.

# Introduction

With a daily food budget of USD\$0.60, Reeti lives with her husband and their two children, ages three and fourteen, in semi-urban Sindhupalchok, Nepal. Even though her growing children ask for them, she has no regular access to milk, eggs, or meat. Reeti and her husband grow rice and maize on their farm and supplement this with biscuits and chow chow (instant noodles) purchased at the nearest grocery store, an hour's walk away. She buys vegetables with longer shelf lives, like potatoes, onions, garlic, and cauliflower, and gets fresh vegetables when she can. Due to limited cash flow, Reeti must buy in small portions, and she worries that she's not giving her children the nutrition they need in order to grow into healthy adults. She needs nutritious food options within her financial reach, and she's not alone in that need.

## **The Challenge: Serving Nutritionally Vulnerable Populations**

Lack of availability of affordable, nutritious foods is a major problem in low- and middle-income countries around the world. While lower-income consumers spend most of their income on food, many healthy foods, such as eggs, are simply unaffordable to them. Unsurprisingly, bulk staples comprise the majority of people's food consumption, and the relative share of the food basket and wallet occupied by staples is much greater among poorer populations. For many, animal-sourced foods are still regarded as out of reach, and other perishable healthy foods are often not consumed in sufficient quantities or frequently enough to fully fill nutritional needs. Lack of knowledge about nutritious food choices, or the low appeal of those food products, further compounds the problem.

As a result, many lower-income consumers do not achieve the minimum dietary diversity (MDD) needed to ensure adequate intakes of vitamins, minerals, and other essential nutrients. The World Health Organization recommends that children consume at least four different food groups a day as a minimum, and findings from the International Food Policy Research Institute suggest that children who reach this MDD threshold are 22 percent less likely to be stunted.<sup>1</sup> However, few developing countries have reached this threshold, with just 19 percent of children in countries such as India and Nigeria consuming sufficiently diverse diets.<sup>2</sup>

The 2013 Lancet Global Burden of Disease study highlighted that many of the leading risk factors for both chronic and infectious diseases are linked to low-quality diets, which, in turn, undermine the health and development of low- and middle-income economies.<sup>3</sup> Undernutrition is an urgent challenge, yet nutrition is largely a neglected area of global health and development. Less than 1 percent of global foreign aid goes toward nutrition annually.<sup>4</sup> Meanwhile millions of children die every year, and many more suffer from physical and mental impairments, because they are undernourished or malnourished.<sup>5</sup>

Both public and private sector actors have made previous efforts to deliver nutrition through food products. Micronutrient powders, for instance, were developed to be a low-cost food supplement to deliver critical micronutrients such as iodine, iron, and vitamin A. However, they have struggled to gain traction. Issues of affordability and accessibility are key culprits; other barriers include acceptability issues related to lack of taste, unappealing packaging, and the need to adopt an unfamiliar consumer routine that requires a novel product to be added to and mixed into infants' food. In one program supporting distribution of micronutrient powders in Bangladesh, 19 million sachets were sold in the first one-year period, but a later survey found that fewer than 3 percent of households surveyed were still consuming more than two sachets per week.<sup>6</sup>

We currently have a food system that fails to adequately serve nutritionally vulnerable lower-income consumers. An underexplored opportunity exists to turn to the private sector as an innovation and solution space for some of these challenges, driving both profitable and nutritious outcomes.

### **The Growing Buying Power of Lower-Income Consumers**

It is a common myth that lower-income populations, particularly in rural areas, are not reached by markets or food and beverage companies. In fact, consumers in low- and middle-income countries purchase more than USD\$3T worth of food and beverages through formal food markets each year. Nearly half of that (USD\$1.2T) is spent by lower-income consumers.<sup>7</sup> And the very poor are increasingly consuming purchased and processed food. For lower-income urban consumers, 75 to 90 percent of their food is purchased (as opposed to home grown), and processed foods represent 50 to 70 percent of the monetary value of that purchased food. About 40 percent of the value of the rural food basket is purchased and about 25 percent is processed.<sup>8</sup> Because many of today's processed foods tend to lack nutritional density, however, the quality of lower-income consumer diets remains an issue.

Worldwide, an increase in urbanization and per capita income is driving higher consumption of purchased, processed foods. Between 2008 and 2013, sales of processed foods such as instant noodles and malted dairy beverages increased ten times faster in emerging markets than in high-income countries.<sup>9</sup> Rapid urbanization and increases in per capita income growth in Sub-Saharan Africa, for example, have transformed patterns of demand. Rates differ vastly across the region, but, on average, urban populations are growing at 4 percent, whereas rural populations are growing at 1 percent. Overall, per capita income growth is at 4.6 percent. Over the last twelve years, the overall level of demand for purchased food has doubled.<sup>10</sup> A 10-percent increase in income is associated with a 14-percent increase in consumption of processed foods, a 9-percent increase in consumption of animal-sourced foods, and only a 3-to-4-percent increase in consumption of cereals, roots and tubers, and legumes.<sup>11</sup>

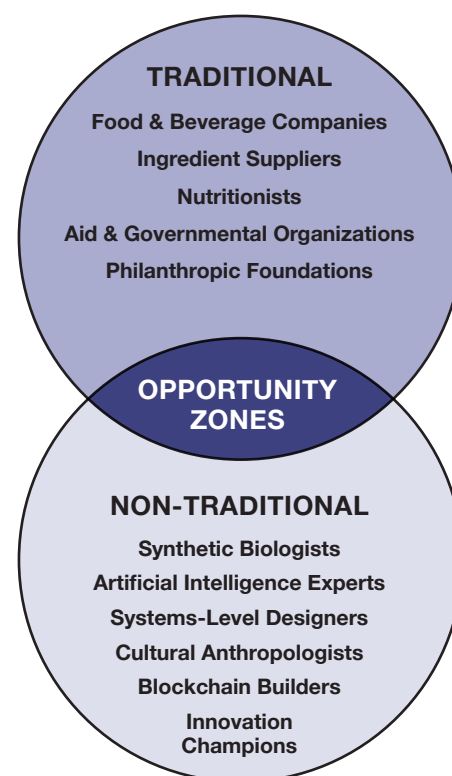
## Opportunities for the Private Sector

Despite meaningful interaction between lower-income consumers and formal food markets, nutritious foods are still infrequently part of the overall food basket of these consumers. Because the lower-income population has historically been treated as a target for food donation rather than as a market, there has been a lack of innovation in the quality and cultural appropriateness of foods delivered.

The private sector can be an immensely powerful actor to reduce malnutrition, sustainably and at scale; but engagement to date has been limited, and affordability has been a significant barrier. It's time for a bold and ambitious strategy that delivers potentially game-changing innovations to create a world filled with more affordable, accessible, appealing, and nourishing foods.

To kickstart fresh thinking about how our market-based food system can play a key role in improving the health of nutritionally vulnerable populations in low and middle-income countries, the Bill & Melinda Gates Foundation and the Institute for the Future hosted a first-of-its-kind two-day summit in Singapore in March 2018. We brought together a small group of global thought leaders and experts to take a mid-to-long-term ambitious view, asking what innovations might lie just ahead on the horizon. To think big and to produce truly new ideas and solutions, we gathered a diverse group of thinkers, entrepreneurs, and implementers from the food and beverage industries along with experts in nutrition and other domains like synthetic biology and artificial intelligence. Together, we created an initial broad vision for how we can design products that are affordable, accessible, appealing, and nutritious for lower-income consumers of the future.

Building on the concepts generated at the summit, we identified five opportunity zones for creating affordable and nutritious foods in lower-income markets. These opportunity zones describe promising new pathways for addressing old problems, but their potential impact for lower-income consumers is limited by a lack of investment from the food industry.





Each opportunity zone is supported by:

- › **four drivers** from the realms of science, technology, and the environment that explain why it is an emerging zone ripe for investment right now;
- › **two forecasts** of emerging innovations that indicate how these opportunities could be leveraged to meet nutritional needs and demands in the coming decade;
- › **six signals** of change that exist in the present and are building blocks that point toward a future of these forecasts; and,
- › **five insights** to help food industry leaders translate these opportunities into concrete strategies and actions to capitalize on the opportunities at hand.

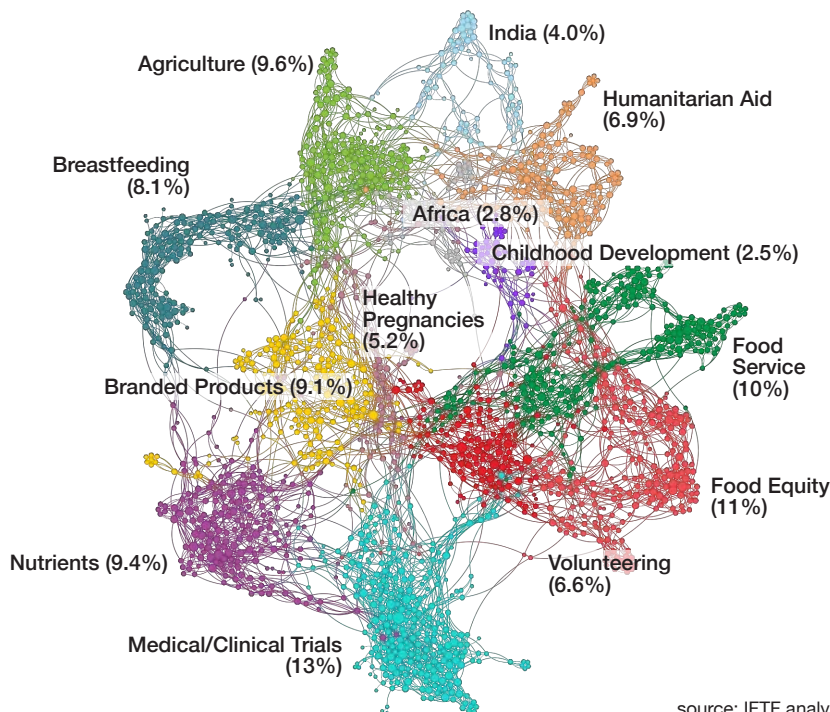
These opportunity zones and their related forecasts are not predictions of the future. There are far too many variables—creating far too much noise in the system—to be able to accurately predict what the world will look like a decade from now. They are also not isolated solutions in themselves; silver bullets to solve challenges as complex as affordable nutrition are more fiction than fact. Instead, these forecasts are designed to push those who are focused on affordable nutrition to imagine different possibilities from those currently being explored. They offer multiple approaches to different angles of this challenge. The hope is that all of these together can help mitigate risks for business and inform the creation of sustainable business models so that the private sector can begin offering affordable nutrition where it is most needed.

**How This Report Differs from Global Discourse on Affordable Nutrition**

To test whether the opportunities identified through our expert convening and further research were truly unique possibilities that have been underappreciated or overlooked, we needed to better understand the current global discourse around affordable nutrition. To do that, we turned to the power of machine intelligence by partnering with Quid, a San Francisco–based start-up

whose natural language processing software can read millions of news articles and blog posts and synthesize them visually. A team of researchers used Quid to create a topographical map of the public narrative on affordable nutrition around the world, surfacing key thematic clusters.

Each node in this network represents an article related to affordable nutrition published online over the past four and a half years across the globe. Each article has been grouped by its semantic similarities to other articles in the network, creating colored clusters that show us the major themes that are discussed around the world related to affordable nutrition.



source: IFTF analysis

While not entirely absent from all articles, the opportunity zones described in this report are not represented in any large or particularly meaningful way in the current discourse. By investigating the impact of new business models and technologies that may have previously been ancillary to nutrition, we can identify investments that have the potential to fundamentally change the affordable nutrition landscape. We believe this topographic map of topics currently discussed regarding affordable nutrition demonstrates that the opportunity zones identified in this report are truly uncharted territory worth exploring.

While the challenges are formidable, we believe significant opportunity for innovation exists within our market-based food system to improve the health of nutritionally vulnerable populations.

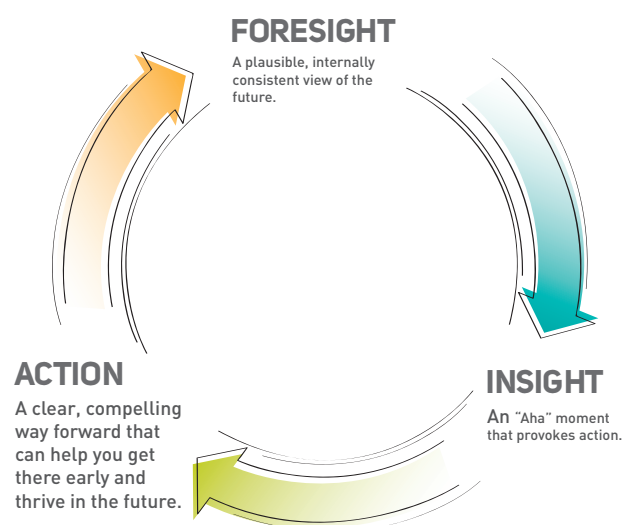
### The Foresight-Insight-Action Cycle

The Institute for the Future uses a process called the Foresight-Insight-Action cycle as a framework to structure all research.

**Foresight** is the process of turning facts about the present into clear and actionable views of the future. Often, this is communicated in the form of a forecast—a plausible, but not predictive, assertion about the future. In common use, forecasts are almost always quantitative, but in foresight practice, forecasts can be both quantitative and qualitative as long as they are grounded in present-day facts. The forecasts in this report are intended to challenge your assumptions and encourage you to consider new possibilities that exist for the private sector to engage with the future of affordable nutrition.

**Insight** is the “aha!” moment when we begin to translate our foresight into implications for the choices we face. In the end, our insights point us toward opportunities we can begin to pursue today, threats we need to avoid, and visions of long-term aspirations and preferred futures. As you’re reading this report, consider how the forecasts of future possibilities would change your current strategies.

**Action** is the last step of the cycle—choosing a clear and compelling way forward. With foresight and insight in hand, we are ready to act. Here, we visualize potential actions across an organization, identify and engage networks of collaborators that cross conventional boundaries, and brainstorm experiments to refine strategic efforts.



## INTRODUCTION

The goal throughout this cycle is to identify new products, services, business models, and approaches that will get the right food to the right people at the right price. The future of affordable nutrition can be good business, not just charity. Making nutritious foods affordable for lower-income consumers helps new generations of global citizens with follow-on impacts in health, education, economic development, and more.

Four stakeholder groups encapsulate the pioneering partners with whom the Bill & Melinda Gates Foundation would like to engage and for whom we hope this foresight report enables meaningful insights and actions in the world:

- › National and regional food and beverage companies
- › Multinational food and beverage companies
- › Innovators
- › Input suppliers to the industry

OPPORTUNITY ZONE



# AI COLLABORATION

Toward improved products and better-educated consumers



## AI Collaboration

A major barrier for food companies to better target lower-income and geographically marginal markets is a lack of high-resolution data on this population and their needs. Massive amounts of data are being generated by people in highly networked locations, and thus most of the attention has been given to markets in large cities in industrialized nations. The billions who are still not directly connected, or only sporadically connected, don't yet generate the data needed to make deep inferences. But they are catching up quickly and may soon surpass the developed world in connectivity. When this happens, big data analytics combined with artificial intelligence can provide a powerful lens on lower-income consumers at population, community, and individual levels.

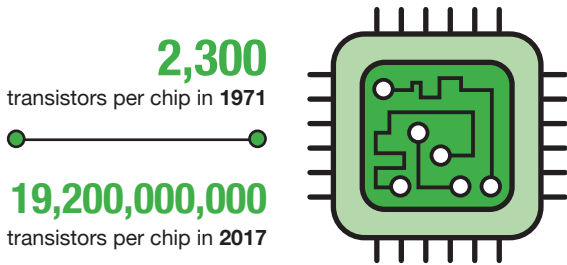
As AI expert and entrepreneur De Kai noted in an interview conducted for this report, "Much of the developing world is leapfrogging the path of development that we have in the developed world. They may be under the radar and they may have trouble with even clean running water, but everybody is getting these smartphones and getting online." As the developing world becomes more connected, AI tools can be deployed to make the best use of available data such as social media posts and usage patterns to give food companies a better sense of what these consumers want and need. Such intelligence can be the basis of successful product design.

AI can also be deployed to help lower-income consumers choose the most nutritious foods for themselves within their means. Providing people with information and research (even credible and well-articulated) has proven ineffective in actually changing long-term behavior.<sup>13</sup> This is especially true for eating habits and nutritional choices, which are notoriously hard to influence because of the big lag between the food decision and the observable health impact. This is where AI can help. Right-timed, right-placed nudges from a well-designed AI assistant can be much more effective at helping people develop healthy food habits, steering them away from empty calories and toward real nutrition.<sup>14</sup> When AI coaches become widespread, producers of foods with high nutritional value will be the big winners.

“ When people talk about AI and the things they can do, there is a lot of focus on commercialization. But there is a lot of benefit for social good too... And there is nothing wrong with trying to do both at the same time.”

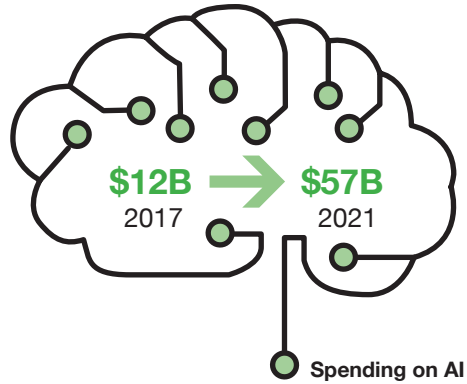
**Neil Sahota, World Wide Business Development Leader at IBM Watson<sup>12</sup>**

COMPUTING POWER



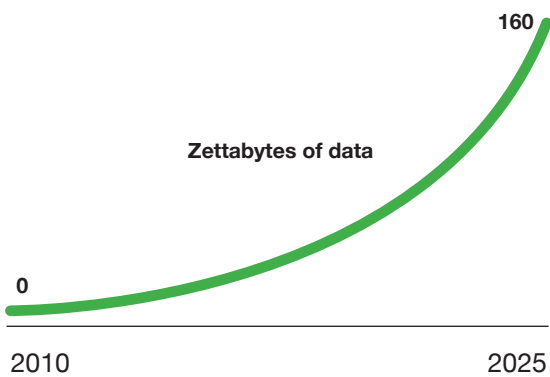
Massive gains in computing speed are driving advances in AI. Over the past five decades, Moore’s Law—which observed that the number of transistors that could fit on a circuit would double every two years—has been generally found to be true. We have gone from about 2,300 transistors per chip in 1971 to 19.2 billion transistors per chip in 2017.<sup>15</sup>

INVESTMENT IN AI



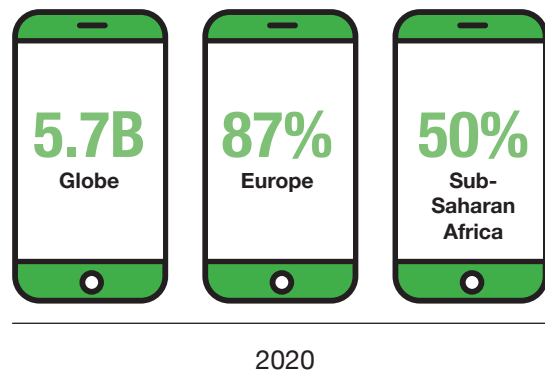
Big money is pouring into the AI and machine learning sector. International Data Corporation (IDC) projects that spending on AI will increase from USD\$12B in 2017 to more than USD \$57B by 2021.<sup>16</sup>

CAMBRIAN EXPLOSION OF DATA



AI gets smarter with more inputs. IDC estimates that the global datasphere will grow to 163 zettabytes (a trillion gigabytes) by 2025—ten times the 16.1ZB of data generated in 2016.<sup>17</sup> Increasingly, this data is semantically structured, enabling and accelerating logical inferences and meaningful intelligence.

MOBILE PENETRATION AND BEHAVIORAL INFERENCE



An estimated 5.7 billion people will have mobile phones by 2020. Mobile penetration is expected to push toward 90 percent in the developed world, including lower-income communities, and to reach 50 percent in Sub-Saharan Africa,<sup>18</sup> allowing for information to reach almost all the world’s population.



## Big data makes it easier to serve lower-income consumers

### From inadequate access to AI-enabled efficiencies

Lower-income consumers have been the target of humanitarian aid groups and development schemes but have less frequently been the main focus of large food companies. Decades of great promises made about the potential of this market sector have rarely panned out.<sup>19</sup> In the next decade, however, data about people, their environment, their health, and their diets will become an abundant resource even in highly resource-constrained environments and will be utilized by AI platforms to create new, low-cost strategies for meeting the nutritional needs of these consumers.

Large food companies are currently investing significant capital and resources in AI, machine learning, and data analytics to create personalized and localized insights for high-income markets. Two unique aspects of these software platforms make them ripe for application in lower-income settings as well. First, the more data they consume, the more insightful they become, so even insights from lower-income markets help make the software smarter. Second, once the software is developed for a target audience, the marginal cost to deploy it elsewhere is almost zero. AI platforms being developed at high cost for high-income markets will be a cheap strategy for growth in lower-income markets as well.

Operational costs are still high for reaching these lower-income markets, and the “low price, low margin, high volume” model is not sustainable unless penetration rates exceed 30 percent.<sup>20</sup> However, AI efficiencies can be won throughout the supply web and cost savings found at every point of exchange. Natural language processing and other semantic tools will speed up and cheapen the analysis of survey data to draw actionable market insights about lower-income consumers.

AI will also be applied to formulating products. As more data about food and nutrition is digitally cataloged, vast opportunities emerge to design nutritious foods that leverage local ingredients and culturally relevant form factors. Over the next decade we’ll see food companies utilize more data from lower-income consumers to design nutritious products at affordable prices.<sup>21</sup> Cracking the code of lower-income consumer preferences and creating effective combinations of goods, services, logistics, and costs will open up new markets with billions of consumers.



MaassMedia

### Natural language processing for survey analysis

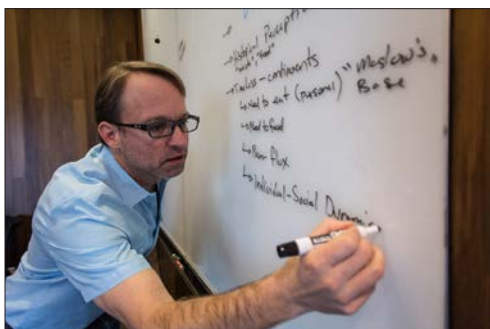
MaassMedia, a digital analytics agency, uses a natural language processing tool to improve the speed, breadth, and accuracy of interpreting their survey results. The tool speeds up the process of analyzing written or free-form responses and reduces human error and bias in the analysis. Tools like this enable marketers to glean insights from unstructured, subjective data about people's emotional responses to and opinions about a subject or experience.<sup>22</sup>



Nutra Ingredients

### AI discovery of food-derived peptides

Nuritas, a biotech company founded in 2014, uses AI, deep learning, and genomics to rapidly and efficiently predict and then provide access to food-derived peptides (biologically active molecules that are critical in reducing and regulating the onset of certain chronic degenerative diseases).<sup>23</sup> Nuritas has partnered with leading food and beverage companies to deploy their novel technology platform that identifies highly efficacious peptides from natural sources and validates the efficacy of those discoveries within target food applications.<sup>24</sup>



Tarek Amin, Medium.com

### The Internet of Food (IoF)

Dr. Matthew Lange at the University of California, Davis, is building a new scientific discipline called food informatics through his research on the Internet of Food. The IoF is a semantic web that captures the global, evolving knowledge base of data on food, agriculture, diet, environment, and health. AI and machine learning rely on data being standardized, accessible, and interoperable, and the IoF is an effort to do just that: harmonize and structure food vocabularies.<sup>25</sup>





# AI assistants guide personalized food choices

## From burdensome decisions to high-touch smart nudges

The burden of making good food choices weighs heavily on all of us, especially on those with a limited budget and/or limited access to healthy food and nutritional information. Today, AI assistants—accessible through an app interface, for example—can help you prepare your food and create optimal taste combinations personalized for you, your family, or your organization. Over the next decade, these AI platforms will become a powerful ally for lower-income consumers navigating complex and burdensome nutritional choices where information is not always available or actionable.

Imagine a future in which your food choices are supplemented by advice and nudges from your AI assistant. This assistant can analyze your genetic information, life stage, personal and family history, mood, taste profile, energy needs, values, and other internal factors. It can also access up-to-date comprehensive data on nutrition research, environmental impacts, costs, and other external conditions. It can analyze your budget and direct you toward low-cost, healthy alternatives.

The data and communication styles used by these AI assistants can be adapted to communities and individuals, possibly overcoming “one-size-fits-all” strategies based on a middle-class urban twenty-something. In addition, because lower-income consumers are often more suspicious of surveillance and abuse of data,<sup>26</sup> persuasive strategies can be consciously designed for alternative expectations, life situations, and preferred modalities of communication. High-touch services, which are especially important in smaller village contexts, can be facilitated through automated systems and conversational interfaces.

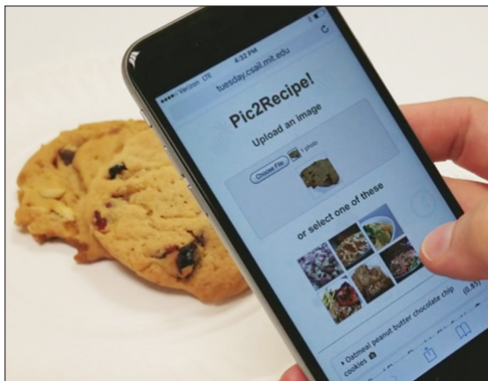
The first-level of benefit of an AI assistant might be improvement in health and budget outcomes, but it will also help with reducing cognitive load (we make an average of 227 food decisions a day, whereas we think we make only about 15)<sup>27</sup> and increasing willpower over the day. At the family level, a program that has AI-backed authority might help parents convince their kids to improve their food choices and eating habits. At the community level, if individual data is linked with other health data, an early warning system for emerging conditions or diseases could be created.



HealthifyMe

### AI-powered app for personalized health coaching

HealthifyMe is an India-based AI-powered health and diet coaching mobile app available 24/7 through a conversational interface. The app combines coaching from India's top nutritionists and trainers with AI, named Ria, that creates personalized diet plans and workout routines based on a user's goals. Ria is powered by "150 million food logs, 15 million messages, and over a millennium of experience" and continues to improve as more users interact with the app.<sup>28</sup>



Fine Dining Lovers

### Nutrition data from food photos

Pic2Recipe is a computer vision system developed by researchers at MIT's Computer Science and Artificial Intelligence Laboratory (CSAIL) that analyzes photos of food and distills information about the food's ingredients. Technology like this could be used to track daily nutritional information over time through simple photographs.<sup>29</sup>



Comet Labs

### Personal AI with ethical guardrails

Akin is a Sydney-based start-up building AI that can autonomously solve complex problems and form deep and trusted relationships with humans. The company is a public benefit corporation that is leading the field in developing ethical AI systems based on relationship building to achieve human-centric goals, not just sell products. Akin is researching how personal AI will change our relationship with food, and how practical ethics and AI can improve human well-being.<sup>30</sup>

# Insights

## for Affordable Nutrition

### Use AI for New Product Discovery

New product development for lower-income populations can be augmented with the help of AI, which can simultaneously weigh many variables, such as cost, taste, nutrition, and cultural context. AI can rapidly evaluate thousands of potential new ingredient combinations, making this process much cheaper than if done by a team of human food scientists.

### Remove Bias and Extend the Reach of Surveys

Natural language processing software offers the opportunity to interpret qualitative surveys and ethnographies in a more accurate and insightful manner in order to learn about the unmet consumer needs and shifting values of lower-income consumers, and to identify new market opportunities. The low cost of analysis involved and the wider segment of the population that can be reached mean that food companies can generate better consumer insights across the entire income spectrum.

### Scale High-Touch Relationships

Conversational AI interfaces—both through voice and text—create opportunities to scale interactions and relationships that once relied on in-person exchanges and close networks of trust. Mobile chatbots at information kiosks can improve nutritional literacy by communicating with consumers in a culturally appropriate way, in real time and at lower cost. Once this software is developed, it can be deployed around the world at very little added cost.

### Turn Data Into a Valuable Resource

Anyone interested in lower-income consumers needs more data about them in order to design more effective products that resonate in these markets. A food company with sufficient market penetration has a rich source of consumer data and therefore has a sellable resource. Use AI to do analytics on these datasets to create new products that can be monetized.

### Capitalize on Minimal Deployment Costs

Once you have a reasonably good piece of software or machine intelligence that you have developed for high-income markets, deploying it in other markets approaches zero marginal cost—meaning the cost of scaling from high-income to lower-income consumers is very small. Besides, the more data the software collects, the smarter it gets.

“ Artificial intelligence has the potential to accelerate towards a dignified life, in peace and prosperity, for all people. The time has arrived for all of us—governments, industry, and civil society—to consider how AI will affect our future.”

**UN Secretary-General  
António Guterres<sup>31</sup>**

OPPORTUNITY ZONE



# TRADITIONAL WISDOM

**Toward reincorporating time-honored health  
practices and ingredients**



## Traditional Wisdom

Traditional culinary and agricultural wisdom, discovered through many generations of trial and error, can be used to inform development of new food products for lower-income consumers that are both scientifically grounded and culturally relevant. This wisdom encompasses traditional ecological knowledge (TEK),<sup>33</sup> acquired by indigenous peoples over thousands of years, as well as teachings on food and health such as those embodied in traditional Chinese and Ayurvedic medicine. Traditional knowledge is often passed down informally through community practices, oral history, and family networks. Such knowledge is in danger of being lost as younger generations are drawn in by processed foods and as farmers shift toward growing commodities for export.

Now the opportunity exists to use cutting-edge science to validate ancient approaches to diet, as well as to formalize how we track, share, and apply that knowledge. Already food businesses are using advanced science to understand traditional food knowledge and adapt products for a larger global market.<sup>34</sup> Food entrepreneurs are also coordinating with development and aid efforts to establish the raw material inputs needed for successful new products based on traditional ingredients.

Blending traditional culinary knowledge with innovation will sometimes be about making new ingredients taste like old favorites and other times transforming nutritious staple foods, such as lentils or sorghum, into meals and snacks that are delicious and exciting for today's younger consumer. Recasting traditional knowledge will require effective storytelling and branding to differentiate these products and overcome negative or outdated associations with the ingredients. For example, Patanjali Ayurved Ltd, an Indian FMCG company started by yoga guru Ramdev, has reframed traditional Ayurvedic ingredients and principles in a contemporary context and was named the most trusted brand by the Brand Trust Report India Study 2018, beating out big multinationals.<sup>35</sup>

The commercial opportunities for these foods extend far beyond lower-income markets. Consumers across the income spectrum are embracing novel and nutritious ingredients with lower environmental impact. For example, a popular Australian breakfast cereal company recently created a gluten-free line using sorghum. This meets growing market demands for gluten-free foods while also encouraging local farmers to grow more diverse crops by guaranteeing them a market. The challenge for food companies is to focus attention on how new ingredients and products based on traditional wisdom can address the specific needs of lower-income consumers for affordable nutrition. This will ensure that food companies are not simply exploiting local knowledge for high-income markets, as has been well documented with the popular rise of quinoa.<sup>36</sup>

“ It’s not only about creating new markets and new products, but importantly being able to share a portion of those revenues and specifying there should be fair and equitable benefit-sharing back to those countries that originated the biological assets in the first place.”

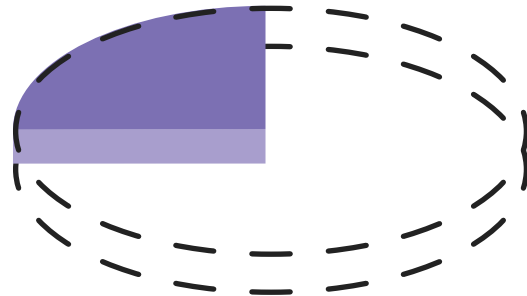
**Juan Carlos Castilla-Rubio,**  
chairman of Space Time Ventures  
and founder of  
Earth Bank of Codes<sup>32</sup>

### DNA SEQUENCING



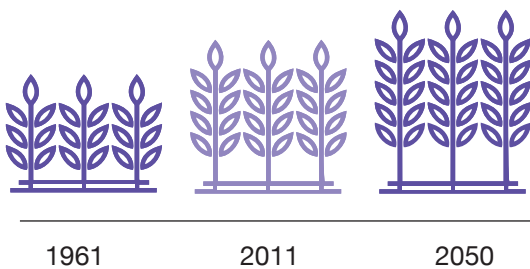
In the last twenty years, the cost of whole-genome sequencing has gone from more than USD\$100 million to less than USD\$1,000. Easy access to high-throughput DNA sequencing is creating a proliferation of experiments in research labs all over the world to explore the causal mechanisms behind centuries-old food and health practices and ingredients.<sup>37</sup>

### AGROBIODIVERSITY LOSS



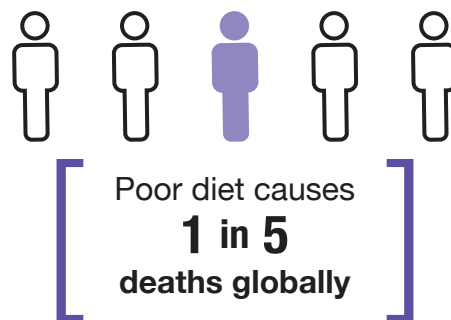
Over the last century, 75 percent of plant genetic diversity has been lost as farmers have shifted toward genetically uniform, high-yielding varieties. Today, 75 percent of the world's food is generated from only twelve plants and five animal species, creating an urgent need to restore agrobiodiversity and an opportunity to reintegrate traditional ingredients into food production.<sup>38</sup>

### CLIMATE CHANGE



Between 1961 and 2011, global GHG emissions from agriculture nearly doubled, and they could increase another 30 percent by 2050. Food producers around the world are seeking new ways to adapt to increased drought and extreme weather events, and many are looking to the practices of indigenous people to learn how to be better stewards of the land.<sup>39</sup>

### GLOBAL DISEASE BURDEN



The 2016 Global Burden of Disease Study found that poor diet is a factor in one in five deaths globally. Across all income levels, as people link the ubiquity of processed snacks in emerging markets to rising rates of chronic disease, they will seek food alternatives that help and not harm the body.<sup>40</sup>



## Eating becomes evidence based

### From intuition in the kitchen to evidence in the lab

The active ingredient in aspirin was first documented by ancient Egyptians who used the bark of the willow tree for pain relief, which became a common practice among indigenous peoples around the world.<sup>41</sup> There are now countless examples of modern scientific inquiry proving the efficacy of traditional practices and bringing them into mainstream use. However, often these appropriations occur without any nutritional or health benefit getting back to the community of origin. And during the last fifty years, much of this traditional wisdom has been lost in the food system.

Nutritious grains such as millet and sorghum have been pushed off the plate by less healthy alternatives such as wheat, rice, and soy. For example, between 1962 and 2010 in India, per capita millet consumption dropped from 32.9kg to 4.2kg while consumption of wheat almost doubled, from 27kg to 52kg.<sup>42</sup> Shifting a portion of cereal consumers back to their culinary roots through ingredients such as millet can improve the health of both consumers and the environment.

Traditional wisdom can be reintegrated with modern food production by building a scientific evidence base for why certain ingredients and preparation techniques work the way they do. With access to advanced genetic and microbial analysis tools, R&D teams can understand the science behind long usage of food as medicine or to achieve delicious flavors. In addition to using this new evidence to make novel products for wealthy consumers, food companies can address urgent challenges in malnutrition and obesity as well as other noncommunicable diseases by identifying low-cost ingredients that are also culturally familiar, highly nutritious, and less resource intensive to grow.

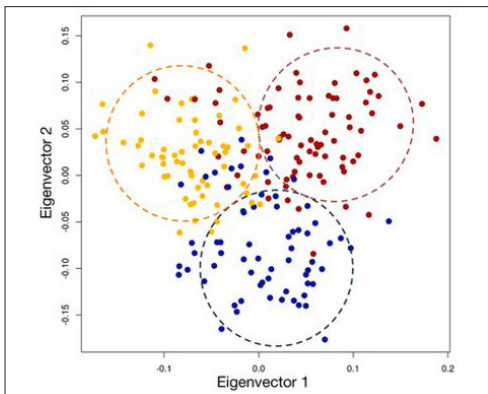
To effectively attract consumers, these ingredients may need a makeover. Food companies may need to showcase them in the same appealing form factors and packaging that even the poorest consumers have become accustomed to with packaged foods. Using local ingredients, local labor for manufacturing, and even engaging local artists for fun packaging or marketing campaigns will create additional economic benefits for lower-income communities as well as help big brands build local trust.



ICRISAT

### New visibility for traditional ingredients

The Smart Food initiative at International Crops Research Institute for Semi-Arid Tropics (ICRISAT) is developing innovative methods to make nutritious and drought-tolerant foods such as millet, sorghum, and grain legumes attractive again in Africa and India. Smart Food projects include a reality TV show in Kenya that challenges contestants to incorporate these ingredients, and support for companies that make appealing foods with these ingredients.<sup>43</sup>



Periyasamy Govindaraj et al., "Genome-wide Analysis Correlates Ayurveda Prakriti," *Scientific Reports*, October 29, 2015, Figure 2.

### Genetic underpinnings of Ayurvedic body types

A Nature Scientific Reports study performed a genome-wide analysis of 262 individuals and found allelic differences that correlate with the three Ayurvedic body types. This suggests that the phenotypic classification of India's traditional medicine has a genetic basis and could contribute to modern efforts for personalized nutrition.<sup>44</sup>



MoringaConnect

### Global markets for local superfoods

Aid organizations have spread moringa trees throughout rural Ghana because the leaves and seeds provide many essential vitamins and nutrients. However, without a connection to global markets, the benefits of these trees are not widely distributed. MoringaConnect guarantees farmers a market for moringa, and through value-added processing creates food and beauty products.<sup>45</sup>





## Food wisdom is digitized

### From local lore to an open internet of food knowledge

Making thousands of years of local food knowledge accessible in order to improve global nutrition is largely a process of translation: turning oral histories and local adaptations into standardized instructions and machine-readable data. A combination of natural language processing, machine learning, and robotics can be used to record and translate agricultural and culinary knowledge and to automate food growing, recipe formulation, and meal preparation. As more agricultural tasks and food manufacturing processes become automated, this digital food knowledge can be downloaded and applied by anyone, anywhere.

An early example of this is the MIT OpenAg Initiative Food Computer. This small-scale indoor growing system allows users to control variables such as temperature, humidity, light, and more. When they find a combination that works, users upload this “climate recipe” so that anyone else with a food computer can download these settings to grow that same food.<sup>46</sup> Imagine setting up a cooperative that records all foods’ properties in a standardized way and then makes that information available to distributed manufacturing systems around the world.

Some communities will be reluctant to share specialized local knowledge with large food companies because it is, in essence, their cultural heritage and intellectual property. Opportunities exist to incentivize contributions to a data commons by ensuring that those who contribute can share in resulting profits. The Nagoya Protocol on Access and Benefit Sharing<sup>47</sup> already gives legal rights to the country of origin of biological material. Expanding on that, an open food knowledge data commons could track who is using that data and automatically pay out on any commercial value that results from it. This will be an opportunity for food brands to rebuild trust and authentically integrate local knowledge for the health benefit of consumers.

This requires thinking very differently about the relationship with consumers. They will become collaborators and co-innovators, not just consumers at the end of the supply chain, and R&D teams will in effect expand to include millions of people all over the world who have worked under constraints to adapt local ingredients. Tackling our most urgent nutrition challenges will require the creative and multidisciplinary thinking that results from this kind of collaboration.



Engadget

#### Automated sorting made available to all

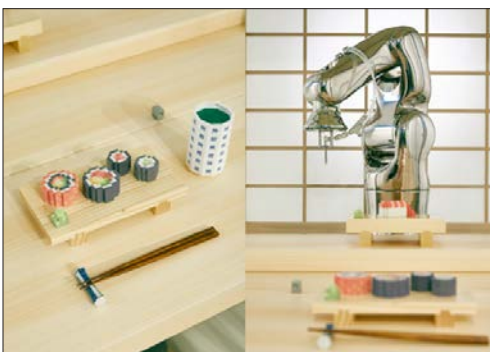
Makoto Koike, a former automotive engineer, noticed how much work it took his parents on their cucumber farm in Japan to sort cucumbers by size, shape, color, and other attributes. The AI-powered sorting machine he built using Google's open-source TensorFlow is now openly available to anyone else who wants to download the plans to make their own.<sup>48</sup>



Earth Bank of Codes

#### Protection of local biological IP

The Earth Bank of Codes is an open digital platform that aims to map the genetic sequences of all living things, apply AI and systems analytics for novel discoveries, and record the provenance of biological IP assets so that communities can benefit from scientific breakthroughs derived from their local resources. At the 2018 World Economic Forum in Davos, the bank announced a pilot project in the Amazon Basin to promote this new bio-based economic development path.<sup>49</sup>



Horecatrends.com

#### Food teleportation with 3D printing

OpenMeal, a Japanese company, debuted "sushi teleportation" at SXSW 2018, calling it "the world's first food data transmission." The sushi was designed in Tokyo and 3D-printed in Austin, Texas. The company is now working on building its Food Base Project, which allows users to share food data and send it to their connected Pixel Food Printer to recreate dishes.<sup>50</sup>

# Insights

## for Affordable Nutrition

### Use Traditional Ingredients to Ensure Food Safety

Today consumers expect that, at a minimum, their food won't make them immediately sick. By 2030, definitions of food safety will include longer-term dimensions of health and nutrition and will increase demand for traditional ingredients that don't cause harm.

### Build the Evidence Base for Nutritious Ingredients

Large food companies with advanced R&D capabilities are well positioned to help build the scientific evidence base around traditional diets and how they deliver important micronutrients. These methods of scientific inquiry can also be applied to discover entirely new foods and techniques that could impact the health and affordability of food.

### Redefine Intellectual Property

Embracing traditional food wisdom will require a different approach to trade secrets and IP. Copying a food's formulation isn't hard, and local communities will want to protect their knowledge from being exploited and commercialized. Platforms such as the Genomic Open-source Breeding Informatics Initiative set an example for how this can be done in agriculture.<sup>51</sup>

### See Consumers as Collaborators

Embracing traditional food wisdom means acknowledging the wealth of knowledge in the stories and traditions of people all over the world. This will require bringing traditional categories of consumer insights and R&D closer together and accelerating new product development through platforms that can track, translate, and share best practices and nutritional wisdom.

### Digitize Food to Allow for Distributed Manufacturing

When traditional knowledge is encoded as data that can be accessed by anyone, anywhere, these ancient practices can be blended with new distributed food production technologies (such as 3D printing). New technologies, such as encapsulation methods, antioxidant peptides, and novel spray drying techniques for vitamins, can also be utilized to improve the stability of micronutrients in traditional foods.

“Thinking of computable flavor is really hard... we have digitized light and sound and now we are building that language to describe flavor. But flavor is a wicked problem because it is subjective.”

**Dr. Matthew Lange,**  
food and health informatician,  
University of California, Davis<sup>52</sup>

OPPORTUNITY ZONE



# MICROBIOTA MANAGEMENT

Toward microbe-friendly diets for optimum health outcomes



## Microbiota Management

When we eat, we feed not only ourselves but also trillions of single-celled microorganisms in, on, and around us. These microorganisms—also called microbes or microbiota—constitute our microbiome. The emerging field that studies our bodies and our microbiomes represents nothing short of a twenty-first-century Copernican revolution of ontology. This research is revealing that we have thousands of different species of microbiota, ranging from bacteria and viruses to parasites and even fungi, occupying our bodies. In fact, our bodies are composed of about ten times as many foreign microbial cells as human cells. Our microbiomes are unique products of our individual genetic makeup and a myriad of environmental factors. These ecological communities are alive, changing daily based on the food we eat, the exercise we get, the medications we take, and the environments in which we live.

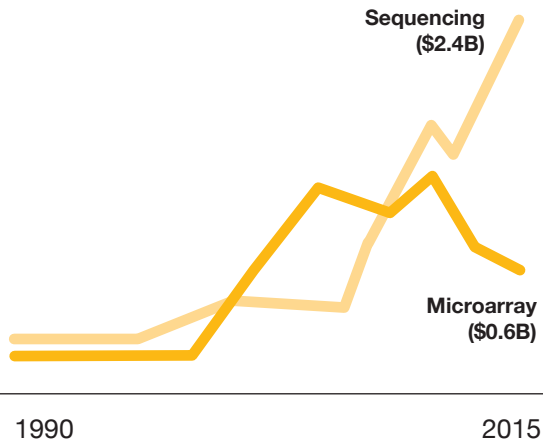
While the science is still emerging, researchers are beginning to more deeply appreciate the impact microbes have on human health. The microbiota are not innocent bystanders but instead critical protagonists in our bodies. Some are helpful while others are harmful. In a healthy human, all microbes exist together in a balanced harmony that stimulates the immune system, breaks down toxic compounds, staves off potentially pathogenic organisms, and synthesizes vitamins and amino acids. When that balance is disturbed, the body becomes more susceptible to disease and distress.

The right foods are essential to maintaining a healthy microbiome. While many cuisines have incorporated foods that are healthy for our gut, like fermented foods, these practices were designed before we fully appreciated the impact microbes have on our bodies. Now advances in cheap microbiome sequencing, microbiome biobanks, and research collaborations are building an evidence base for the impact microbiota have on human health. This is opening up new opportunities for food companies to design microbe-friendly and microbiota-directed foods (MDFs)—a consumer’s microbiome, optimizing for long-term nutrition outcomes that enable health. This can be a special boon for populations that have been undernourished and malnourished, which includes lower-income consumers.

“Microbes matter. We have ignored them. We have feared and hated them. Now, it is time to appreciate them, for our grasp of our own biology is greatly impoverished if we don’t.”

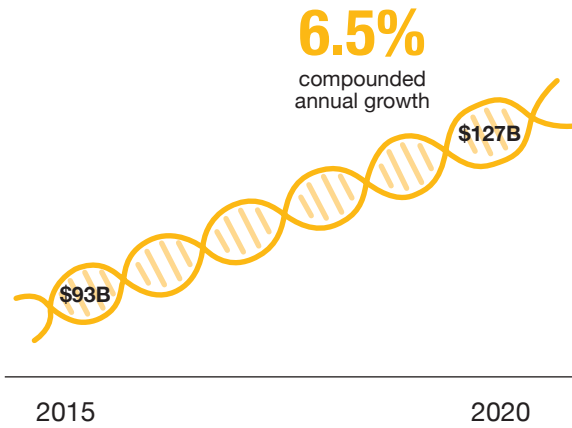
Ed Yong, science writer<sup>53</sup>

**NEXT-GENERATION SEQUENCING**



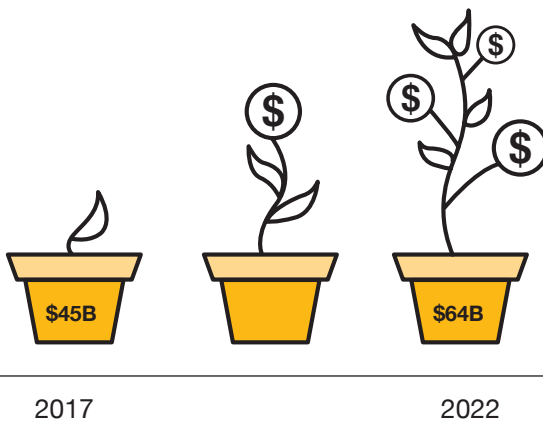
The sequencing technology known as next-generation sequencing (NGS) has fundamentally revolutionized the biological sciences by facilitating unprecedented research into biological systems—including microbial diversity—with its ultra-high throughput. Funding from the National Institutes of Health (NIH) for NGS has increased sharply since 2005, while funding for earlier technologies like microarrays has fallen off.<sup>54</sup>

**PERSONALIZED NUTRITION MARKET MATURATION**



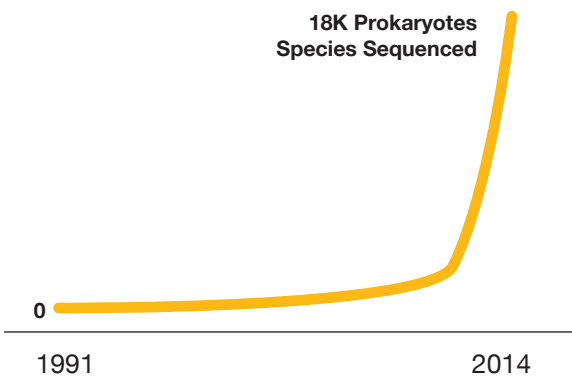
The personalized nutrition market is expected to grow from USD\$93 billion in 2015 to USD\$127 billion in 2020. The steady growth of the personalized nutrition market opens up opportunities to personalize microbes for food and beverage applications.<sup>55</sup>

**PROBIOTICS MARKET GROWTH**



The probiotics market is expected to grow from USD \$45.64 billion in 2017 to \$64.02 billion by 2022, primarily driven by heightened consumer awareness of the health benefits of probiotic consumption. Asia-Pacific is projected to be the fastest-growing region as consumers in countries like China and Japan increase the probiotics in their daily diets.<sup>56</sup>

**SINGLE-CELLED ORGANISM SEQUENCING**



The single-celled organisms, like bacteria, that make up our microbiome are called prokaryotes. While all forms of life have been sequenced, prokaryotes have the largest number of species sequenced, and the number of prokaryote species sequenced is rapidly growing, faster than for any other life-form.<sup>57</sup>



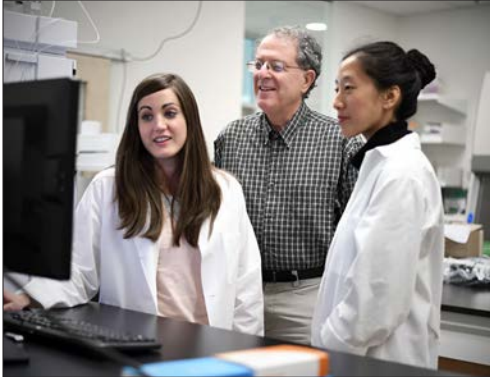
## Foods and diets are designed to be microbe friendly

### From feeding the human body to feeding our microbial partners

Early research findings suggest that microbe-friendly diets are high in fiber from naturally diverse, plant-based sources. If they aren't fed enough fiber, our microbes begin to eat the intestinal lining, causing inflammation and an increased susceptibility to pathogens.<sup>58</sup> Some research suggests poor gut health is causally related to both stunting and wasting in children three years old and younger.<sup>59</sup> Various components of processed foods, like certain additives that extend shelf life and improve texture, appear to be harmful to our microbial health.<sup>60</sup>

Unfortunately, lower-income consumers are increasingly eating purchased and processed food. About 40 percent of the value of the food basket in rural areas is purchased and about 25 percent is processed.<sup>61</sup> Projections modeled on the last five years of growth in urbanization, per capita income, and rates of income inequality anticipate that by 2040, 72 percent of all food will be processed to some degree, up from 58 percent today. Rural processed food consumption will grow from 43 percent to 50 percent and urban processed food consumption from 91 percent to 95 percent.<sup>62</sup>

The opportunity here is for food companies to address some of the major nutritional challenges of lower-income populations through the development of next-generation processed foods that are friendly to the microbiome. As the causal relationship between our diet and our microbiome is better understood, companies will design food not only to be tasty, cheap, and convenient but also to ensure a happy and healthy microbiome. This might involve creating more high-fiber and plant-based products, incorporating bioactive peptides and oligosaccharides into functional foods, and diversifying foods to ensure that consumers can access a microbiota-directed food basket. Without a suitably microbe-friendly food basket, individual products likely will be unable to solve many of these nutritional challenges.



Washington University in St. Louis

### Microbiota-directed foods

The Gordon Lab at the Washington University in St. Louis School of Medicine is developing therapeutics that target the gut microbial community to treat undernutrition in infants and children living in lower-income countries and obesity in westernized countries. Their preclinical trials are identifying therapeutic candidates for microbiota-directed foods (MDFs) and next-generation probiotics that are comprised of human gut-derived microbial strains. The MDFs and next-gen probiotics will enable healthy and normal growth in malnourished children.<sup>63</sup>



TechPress

### Next-generation probiotics at commercially viable scale

DuPont Nutrition and Health has teamed up with the Microbiome Venture at Estonia's Center of Food and Fermentation Technologies (TFTAK) to develop new cultivation techniques and bioprocesses that will produce next-generation probiotics at scale. This partnership will focus on the mother-infant microbiome, the gut-brain axis, and infant nutrition in order to create nutritious fermented foods and beverages.<sup>64</sup>



DayTwo

### Personalized nutrition based on the gut microbiome

DayTwo analyzes an individual's microbiome to predict blood sugar responses to thousands of different foods and creates personalized nutrition recommendations to maintain a normal blood sugar level throughout the day. With a stool sample, a short questionnaire, and a simple glycosylated hemoglobin (HbA1c) blood test, DayTwo clinicians are able to sequence the DNA of a gut microbiome and produce a unique nutrition profile that suggests foods to keep the gut, and therefore the body, healthy.<sup>65</sup>





## Community-level microbial maps inform agile food manufacturing

### From individual self-tracking to communal tracking for consumer insights

Thus far, most microbiome-monitoring start-ups and nutrition plans have been focused on the individual, and microbial variation across average populations has been under-investigated. A new level of consumer insights will be afforded by the accumulation of microbial observations about individuals and synthesis of these observations into high-resolution, dynamic, population-level microbial diversity maps. Analyzing microbial information at the community level will help global food companies develop novel and nutritious products and formulations that address local access and health issues.

Like the weather, these microbial diversity maps will be regularly subject to change, posing a challenge for traditional forms of manufacturing that are slow and expensive to adjust based on dynamic demand. These maps will underpin and inform a flexible, highly distributed network of easy-and-cheap-to-operate plants that create a regional supply of microbe-friendly ingredients. These networks will leapfrog the more expensive, slower-moving traditional forms of manufacturing in lower-income markets where that infrastructure may not currently exist. For example, Amino Labs is already prototyping small-scale and very affordable bioreactors that can turn anyone—from a grandparent to a middle schooler—into a synthetic biologist. While the basic research on and discovery and formulation of food products will be performed by a food company, these low-cost manufacturing platforms designed for nonscientists will make it easier to produce the ingredients that complement a particular community's microbial health.

Some major barriers to better understanding the “average healthy consumer” and real-time microbial dynamics at the population level include a lack of monitoring technologies in people's bodies and environments. With recent investments and developments in distributed, noninvasive health-monitoring technologies and ingestible sensors, the existing challenges can be overcome. Ingestible capsules for measuring gas production within the GI tract have already been prototyped and tested in animals.<sup>66</sup> Over the next decade we can expect to see cheap ingestible sensors that can monitor the gut in real time, as well as some distributed smart toilets and single samples collected during medical treatments.



#### Biobank repository for microbiome research

Created by Harvard T.H. Chan School of Public Health in collaboration with academic and industry partners, BIOM-Mass is a platform that collects, analyzes, and uses microbiome-based specimens. BIOM-Mass is creating the world's most comprehensive human microbiome specimen biobank, cataloging the microbiome profile of more than 25,000 study participants across multiple body sites and combining that data with individual lifestyle, health, and genetic information.<sup>67</sup>



Seres Therapeutics

#### Ecobiotic drugs to establish a healthy microbiome

Seres Therapeutics has built a discovery and design platform to understand the dysbiosis—impaired microbiota—associated with specific diseases and to design tailored therapies. Based on systems biology and comparative genomics, Seres is comparing a vast trove of human data from relevant disease states with that from healthy individuals to characterize specific disruptions and design an entirely new class of therapies—“ecobiotic” drugs made from microbes that catalyze the transition to a healthy microbiome.<sup>68</sup>



Bettinger Group/CMU

#### Ingestible sensors to measure diet and microbes

The US Department of Defense has solicited proposals to develop and validate an ingestible telemetric device for the noninvasive in vivo measurement of bacterial metabolite production within the human gastrointestinal tract. This research is aimed at gaining a deeper understanding of how stressors, host physiology, and the gut microbiome interact—all of which is critical to developing targeted strategies for optimizing human health and performance.<sup>69</sup>

# Insights

## for Affordable Nutrition

### Develop a New Way to Classify Consumers

Broadening consumer categories to acknowledge differences in gut health can open up new avenues for product development and marketing strategies that build on the science of a healthy microbiome.

### Incorporate Low-Cost Ingredients and Production Methods

Relatively low-cost ingredients—like cheap fiber from agricultural waste streams—and novel processing techniques can be used to create microbe-friendly foods.

### Develop New Microbe-Based Health Claims

Community-level microbe maps will help demonstrate a new link between food and health, enabling a larger evidence base to support claims related to nutrition.

### Personalize Products

As everyone's microbiome is unique, microbe-friendly foods will create a new need for personalized nutrition ingredients, products, and business models. Striking the right balance of individual-, family-, and community-level personalization will be critical.

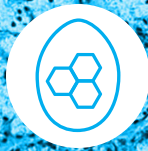
### Move from Transactions to Relations

The need to create more personalized nutrition offerings gives food companies a chance to create deeper ongoing relationships with consumers in place of more singular transactions. Moving from transactions to relations in order to support microbe-friendly foods in the marketplace can help companies build a larger base of loyal customers.

“ Our capacity to uncover how the human microbiome interacts with our organ systems stands to revolutionize how we approach human health.”

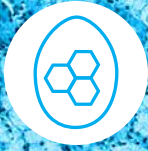
Michelle A. Williams,  
dean of Harvard T.H. Chan  
School of Public Health<sup>70</sup>

OPPORTUNITY ZONE



# CELLULAR AGRICULTURE

Toward reinventing animal-based products at the cellular level



# Cellular Agriculture

Tissue engineers, cell biologists, and biochemists are beginning to understand how to domesticate and manipulate cells into platforms for new kinds of food production. They are using a process known as cell culture, which involves isolating cells from their natural environment and replicating their growth under suitable and controlled conditions. Most applications of cell culture have been focused on biomedical applications, such as growing organs to transplant or skin to graft onto a burn victim. These scientific techniques, however, can also be used for agricultural purposes.

The field of cellular agriculture—the process of creating agricultural products through cell culture—is the beginning of the next agricultural revolution and poses new opportunities to create food that is more sustainable, nutritious, and affordable, and less animal intensive. Animal-based products like meat, dairy, eggs, foie gras, and even gelatin are being created inside laboratories today using two primary approaches. The first involves the culturing of living cells, such as muscle tissue, to create meat. The other involves using a microbe like yeast or bacteria to produce nonliving compounds like the proteins collagen, casein, and whey.

Current industrialized production of animal products is a significant threat to the environment and global health. Livestock farming is one of the largest contributors to deforestation, land degradation, water pollution, and desertification.<sup>72</sup> Viral outbreaks that affect populations across the globe, like swine and avian flu, often originate with the crowded animals on factory farms. Early life cycle analyses of cellular agriculture show potentially large environmental benefits in terms of water and land usage and overall greenhouse gas emissions,<sup>73</sup> although some of those benefits may come at the expense of an increase in industrial energy requirements.<sup>74</sup> There are many unknowns to scaling these production processes, so now is the time to design these systems to maximize the benefits we want and need.

While it may sound like science fiction, cellular agriculture is rapidly becoming science fact. Start-ups creating meat without animals have received investments from companies like Cargill and Tyson Foods and individual investors like Richard Branson. While almost none have products on the market yet, they are looking to successfully scale these technologies with the aim of transforming the way food is produced in every market and geography, including for undernourished and malnourished lower-income populations.

“Decades-old technologies of protein fermentation are now being used to solve the world’s most pressing issues, namely, how to sustainably feed a world with an ever-increasing appetite for animal protein. We desperately need to reimagine food production, and biotech will be a necessary tool to get us there.”

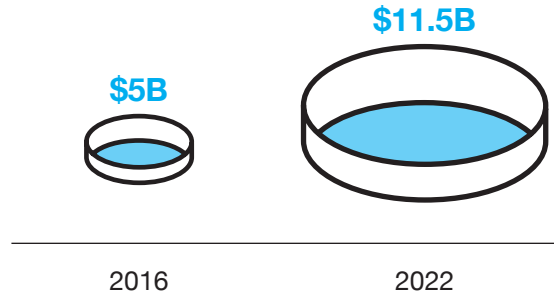
**Arturo Elizondo, co-founder and CEO, Clara Foods<sup>71</sup>**

**INTEREST FROM  
NON-LIFE SCIENCES VCS**



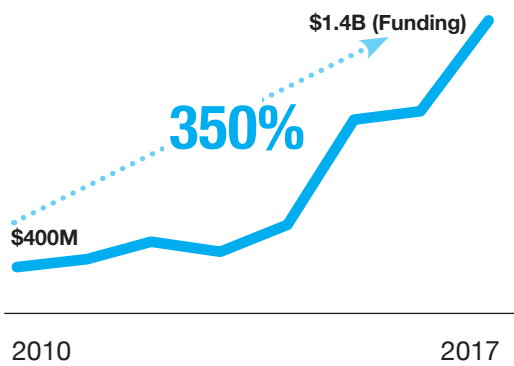
Investment in synthetic biology companies is growing rapidly as the field matures and is increasingly commercialized. More than a hundred investors made their first synthetic biology investment in 2017, signaling a large increase in entrance into the space by investors without a life sciences background.<sup>75</sup>

**TISSUE ENGINEERING  
MARKET GROWTH**



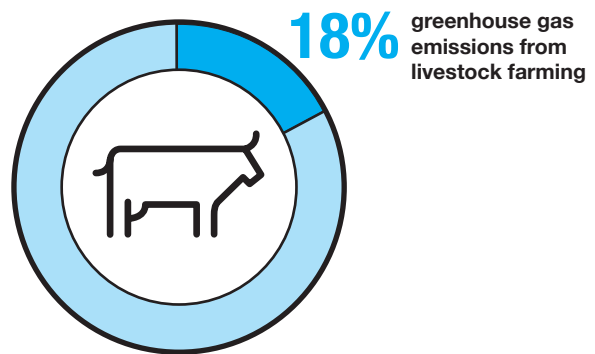
The global tissue engineering market was valued at around USD\$5 billion in 2016 and is expected to reach USD\$11.5 billion by 2022.<sup>76</sup> The growth in tissue engineering for biomedical applications will have spillover effects for other applications of tissue engineering, including agricultural applications.

**INVESTMENT IN  
SYNTHETIC BIOLOGY**



Synthetic biology start-ups raised a historic USD\$1.4 billion in 2017, representing a 350-percent increase from 2010. The growth in synthetic biology investment is outpacing the general growth of start-up funding.<sup>77</sup>

**ENVIRONMENTAL IMPACT  
OF ANIMAL AGRICULTURE**



About 18 percent of global anthropogenic greenhouse gas emissions come from livestock farming, and more than a quarter of the arable land on earth is used for farming animals—representing 70 percent of all land dedicated to agriculture. We are reaching, or have already reached, the natural limit of animal agriculture.<sup>78</sup>



## Basic research biobanks enable more robust innovation

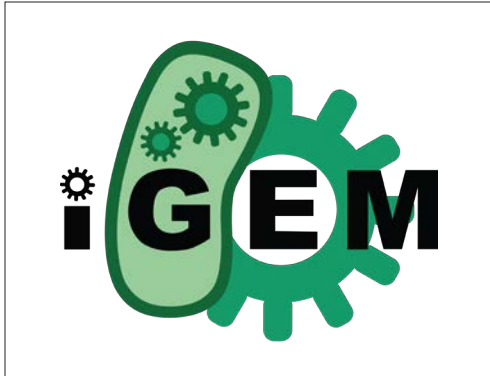
### From venture capitalism to a vibrant commons

A global network of governmentally or philanthropically funded biobanks will collect, store, and disseminate more broadly the basic research underpinning any innovation in cellular agriculture and alternative proteins. This will enable greater experimentation and innovation by actors across the food system who are interested in creating sustainable and nutritious foods at scale. The catalog of research in these biobanks will be filled by synthetic biologists, chemists, food scientists, and others who contribute to an open-source library to accelerate the advancement of cellular agriculture and the use of more novel plant-based proteins.

Currently, every food company has to start from ground zero and spend an immense amount of capital to produce its desired protein output. The challenges are broad and include identifying the appropriate cell lines to culture or the right strains of yeast to engineer, developing the appropriate nutrient mix that feeds these cells efficiently, and architecting bioreactor design at a scale that reaches affordable unit economics. The future will see a much larger commons built by combining the curious and exploratory ethos from the grassroots with the resources and infrastructure from governments, foundations, and even the private sector. A distributed network of biobanks will lower the barriers to entry for cellular agriculture and alternative proteins, enabling more robust innovation by both individual entrepreneurs and large food companies to design foods using novel protein production platforms.

There is precedent for these kinds of biobanks. Communities of bottom-up innovators and DIY biohackers are doing basic research to advance the applications of synthetic biology. The BioBricks Foundation, for example, creates open, standardized sources of biological parts for anyone who would like to use them to engineer something new. New Harvest, a leading nonprofit promoting basic research in cellular agriculture, has promoted the idea of setting up a bank of cell lines to enable broader experimentation in cultured meat.<sup>79</sup>

It isn't just the biology that will be in the commons; protocol, designs, and lab results will also be shared and customized just like open-source software. These advances will only accelerate as biotech continues to be uploaded and distributed in the cloud. Emerald Cloud Lab, for instance, has uploaded a state-of-the-art biotech lab that enables more than forty different experiments to be done remotely with nothing more than an internet connection and a credit card.<sup>80</sup>



iGEM

### Global competition to engineer biology

The iGEM Foundation is a nonprofit organization dedicated to the advancement of synthetic biology, education, and competition through the development of an open community of collaboration. iGEM's main program is the iGEM (International Genetically Engineered Machine) Competition, in which multidisciplinary teams of university students work together to design, build, test, and measure a system of their own design using interchangeable biological parts and standard molecular biology techniques.<sup>81</sup>



Real Vegan Cheese

### Vegan cheese engineered in a biology hackerspace

BioCurious, the world's first hackerspace for biology, has a project called Real Vegan Cheese. More than two dozen biohackers and citizen scientists of all levels are working out of two open community labs to engineer yeast into milk-protein factories. Those proteins are then combined with water and oil to make vegan milk, which is ultimately converted into cheese. All the patentable material is published in the public domain for free use by anyone.<sup>82</sup>



Opentrons

### Automation for open-source laboratories

Opentrons creates robots for scientific laboratories so that biological experiments can be automated, shared, and replicated. No longer is a developer needed to create and run the protocols necessary for biological experiments; those protocols are on the cloud. Such democratized hardware and robotics that uses shared protocols stand to cheapen and accelerate biological research dramatically.<sup>83</sup>





## Food products are biodesigned to deliver health benefits

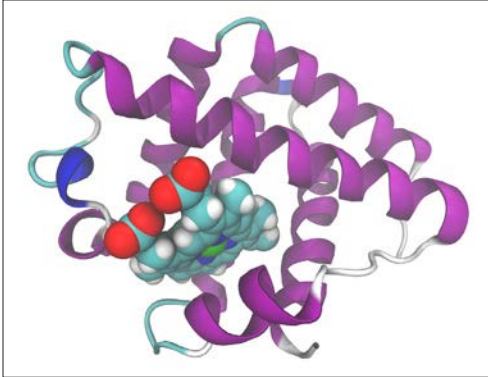
### From empty calories to functional nourishment

Innovations in cellular agriculture and plant-based protein production will converge to create new food products formulated for nutritional functionality. The so-called alternative protein category is expected to reach USD\$5.2 billion in 2020,<sup>84</sup> and synthetic biology will accelerate that projected growth as proteins are increasingly synthesized for food applications.

Biotechnology will enable food products to be designed with novel flavors, unique textures, and enhanced nutritional profiles to deliver health benefits. It also opens up new opportunities to create playful and interactive products with functions like elasticity or the ability to activate properties over time. Synthetic biology–derived alternatives will compete with traditional product formulations.

One product category ripe for reformulation through cellular agriculture is snack foods, which grew by USD\$3.4 billion globally in 2017.<sup>85</sup> Small-quantity, packaged, branded goods such as snacks are a way for lower-income consumers to make cheap and convenient purchases, and they are increasingly doing so. A recent cross-sectional survey found that about 80 percent of young children in low- and middle-income countries are regularly consuming snacks.<sup>86</sup>

Synthetic biology can help turn these products with empty calories into more nutritious foods. For example, the relatively flat structure of potato chips makes them an ideal candidate for early applications of tissue culture, as most cultured meat is grown in very thin sheets. Modern Meadow, a Brooklyn-based synthetic biology start-up, explored how they could use tissue engineering to create a meat chip that has a long shelf life and is both safe and nutritious (having proteins and vitamins without the fat).<sup>87</sup> It doesn't stop at snacks; cellular agriculture will become a platform for optimizing new tastes, enhancing nutrient delivery, and creating more efficient products across the entire food basket.



Wikipedia

### Plant-based burgers that taste like meat

Impossible Foods is creating a new generation of animal-inspired products made entirely from plants. It genetically engineers yeast to produce heme, an important molecule isolated from the leghemoglobin protein found in legumes, which is integrated into its plant-based burgers to mimic the sensory experience of meat. Heme is a particularly valuable source of iron, a lack of which is one of the most common nutritional deficiencies in the world.<sup>88</sup>



FAIRR

### Investor group advocating alternative proteins

The Farm Animal Investment Risk and Return (FAIRR) initiative has released “Plant-Based Profits,” a report backed by almost sixty investors with USD\$2.4 trillion in assets under management, urging global food companies to diversify their protein sourcing away from animal proteins. Major investors like Singapore’s sovereign wealth fund Temasek and prominent industry players like Tyson and Cargill are investing in and developing the alternative protein category.<sup>89</sup>



Clara Foods

### Egg whites without the chickens

Clara Foods is bringing an egg white to the table that is produced completely animal-free, using less land and water while matching the taste, nutritional value, and culinary properties of eggs from hens. Its new ingredient line, Clara Whites, can replace egg whites in angel food cakes, meringues, and macarons. The baking and binding applications team uses a proprietary protein functionality matrix to deliver improved volume, foaming, texture, and tensile strength for innovative food products.<sup>90</sup>

# Insights

## for Affordable Nutrition

### Minimize Input Costs

Animals are very inefficient from an input-output perspective. They require a lot of feed, water, and land compared to what they produce, leading Frances Moore Lappé to proclaim that “we have turned cattle into protein disposal systems.”<sup>91</sup> Cellular food systems can be significantly less resource intensive and can be designed around inputs that are more sustainable, regenerative, and efficient, making nutrition more affordable.

### Secure the Downstream Supply Chain

Supply chains that rely on traditional animal agriculture are increasingly insecure and pose a material risk for companies over-reliant on animal proteins for growth. Cellular agriculture can shore up supply chain insecurities downstream by growing food in a highly controlled environment that is not subject to changes in climate.

### Produce Food Anywhere

Because there are geographic limitations to where animals can be raised for food, animal agriculture requires very complex global distribution channels that add costs. Cell culture decouples food from animal rearing habitats, enabling distributed and hyperlocal food production systems that can minimize distribution costs, logistics, and middlemen.

### Make Production Processes More Efficient

Unlike traditional products like eggs or milk, which contain dozens of proteins and other components, synthetic foods can be engineered to contain only desired components with no extra proteins and molecules. This efficiency can save money, lower environmental impact, and produce enhanced functional properties.

### Optimize Ingredients for Functionality

Most animal-based foods are valued for their varied functionality but are generally one-size-fits-all. This is especially the case with eggs, which are used to bind, thicken, emulsify, foam, and structure products. Synthesized proteins and cultured muscle tissue can be optimized for specific functionality, unlocking new possibilities for food products.

“Cellular agriculture has endless possibilities, including the ability to make more nutrient-packed foods with a longer shelf life, as well as foods tailored for specific uses and preferences, such as meat with lower saturated fat, lactose-free milk, cholesterol-free eggs, or egg whites specifically intended for different baked goods like meringues or fluffy angel food cakes.”

**Christine Gould, founder and CEO, Thought for Food<sup>92</sup>**

OPPORTUNITY ZONE



# PROGRAMMABLE ASSETS

**Toward frictionless transporting and transacting**



## Programmable Assets

As food moves from farm to table, hundreds of questions are asked about it along the way. What's being grown, and where? When and how much was harvested? Who needs it? How much does it cost? Who can ship it? Where will it be warehoused? When can it arrive at the processor? How safe is it? Which stores want it? Is it reaching the right consumer? Is it affordable? How much did they buy? The individual answers to these questions are important—many transactions along the value chain can't be executed without them—and the aggregated answers are invaluable to everyone in the supply chain, from producers to distributors to retailers to consumers. Because this information is often locked away in centralized proprietary databases, tracking it becomes expensive and raises the cost of getting food to consumers.

There is huge room for improvement in the efficiency of food transport and transactions. Any such improvements should decrease the cost of retrieving information; make the supply chain more secure, safe, and autonomous; increase the accessibility and reusability of information across the value chain; and improve distribution. Investable opportunities lie at the intersection of sensors, smart contracts, programmable money, and blockchain protocols. These innovative technologies are being used in combination to establish logistics ecosystems that do away with middlemen and significantly drive down the costs of getting food to lower-income consumers.

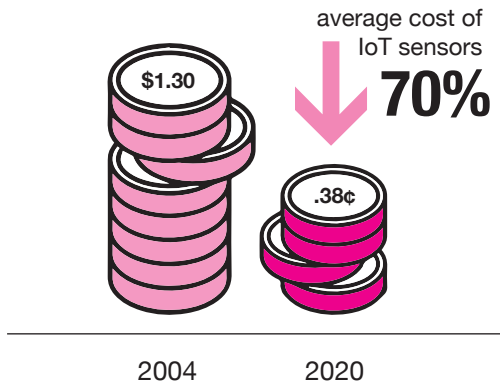
Blockchains are immutable ledgers in which transactions can be added but not changed or deleted. These systems are designed to decentralize marketplaces, speed up payments and settlements, facilitate the exchange of information, and reduce price coercion. For instance, blockchain-based commodity trading can vastly reduce time spent on processing documents and data, enable easy data verification and monitoring of an operation's progress in real time, reduce the risk of fraud, shorten the time it takes to get paid, and free farmers from relying on marketing boards to sell their commodities—all of which can lower costs.<sup>94</sup>

Blockchain protocols are enabling the creation of programmable money, which changes the idea of what money is and how it can be used. Money on a blockchain is fluid, traceable, censorship resistant, streamable, and exchangeable. Cryptocoupons, utility tokens, and smart contracts managed by blockchains will give food companies the ability to inexpensively track food as it moves from farms to processing plants to points of purchase and to incentivize consumers to purchase a healthy food basket.

“ In order for goods to be traceable from farm to fork, all parties that handle the goods should be linked to the blockchain. Once the hurdle of broad participation is taken and the benefits of a more transparent supply chain manifest themselves, laggards will be forced to join fast, or otherwise remain at a competitive disadvantage.”

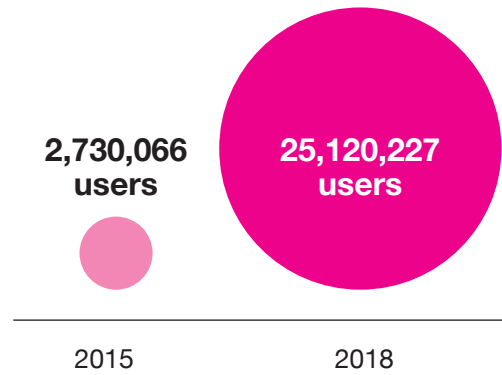
**Harry Smit, senior analyst,  
Rabobank International<sup>93</sup>**

### DECLINING COST OF IOT SENSORS



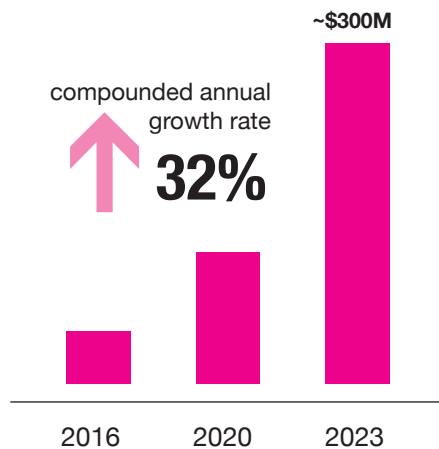
The average cost of IoT sensors used to detect environmental conditions, such as heat, temperature, humidity, altitude, location, and the presence of chemical and biological compounds, is declining and will have fallen 70 percent between 2004 and 2020. Greater use of sensors will enable deeper insights and increase operational efficiency.<sup>95</sup>

### BLOCKCHAIN WALLET EXPANSION



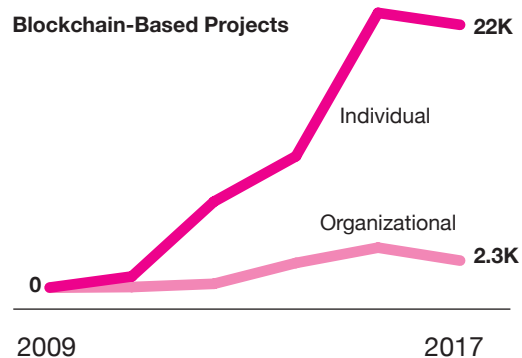
Blockchain wallets store the private keys used to sign digital token transactions. The number of individuals and organizations with bitcoin wallets increased tenfold from 2015 to 2018. As this trend continues, more people will be able to participate in blockchain networks.<sup>96</sup>

### SMART CONTRACT MARKET GROWTH



Smart contracts are an application of blockchain technology that programmatically enforces the terms and conditions of an agreement without a middleman. The global smart contract market is forecasted to reach USD\$300 million by 2023, with a compounded annual growth rate of 32 percent forecasted from 2017 to 2023.<sup>97</sup>

### RISE OF DISTRIBUTED DATABASE PROJECTS



The first application for a blockchain, Bitcoin, was deployed in 2009. Since then, the number of blockchain-based projects has ballooned to the tens of thousands, with applications in security, identity, file storage, attribution, supply chain/logistics, and more. Projects like Hyperledger, launched by the Linux Foundation, seek to advance cross-industry blockchain integration.<sup>98</sup>



## The food supply chain gets a blockchain makeover

### From opaque paper trails to transparent digital records

Food is a low-margin industry. It's very difficult to lower the cost of food itself without either wiping out the profit or reducing the quality of the food. But there's an opportunity for lowering the cost of food without affecting the quality or profitability—by solving for inefficiencies in transport logistics. The food value chain has many stakeholders, and as food moves from one actor to another a great deal of information must be exchanged, retained, and validated. “Food passes through farmers, distributors, processors and retailers, often traveling thousands of miles and changing possession up to ten times prior to arriving in the hands of a consumer,”<sup>99</sup> writes Nathan Jin of Ivy, a start-up that's building a platform to “reduce the friction of information exchange” in food distribution.

The current food logistics system is complex, inflexible, and shackled to twentieth-, and even nineteenth-, century technologies. Transparency Market Research reports that global supply chain logistics cost USD\$8.1 trillion in 2015 and will grow to USD\$15 trillion in 2023,<sup>100</sup> with food logistics being the largest subset. Despite the rapid growth in this already huge industry, not much game-changing innovation has occurred since the introduction of the shipping container in 1956. Many areas of the supply chain still rely on manual, paper-based processes.<sup>101</sup> But as inefficient as the current system is, it works well enough that the interdependent food system stakeholders are somewhat reluctant to expose themselves to the risks and costs associated with adopting a new way of doing things.

Combining blockchain technology and the Internet of Things shows great promise as a way to improve supply chain efficiency and as a result lower the sticker price for food. Food logistics data on a blockchain, collected by wireless sensors, could replace manual inspection and paper records, both of which are subject to human error, redundancy, inaccessibility, and fraud. And because it costs the same to transport a kilogram of low-cost food and a kilogram of expensive food, reduction in logistics costs will result in a proportionally greater reduction in the sticker price for lower-cost food.



scienews.com

### Edible RFID tags

Researchers at Rice University have developed a laser-etching technology that converts the surface of food like bread or an eggshell into graphene (a single layer of carbon atoms). The graphene can be etched to create an edible RFID tag made from the food itself. These tags could give information about where the food originated, how long it's been stored, and the path it took to get to market, and could be linked to historical records on a blockchain.<sup>102</sup>



futurefoodasia.com

### First blockchain agriculture commodity trade

Foodstuffs trader Louis Dreyfus conducted the first agricultural commodity trade on a blockchain in December 2017 to sell 60,000 tons of US soybeans to Shandong Bohi Industry Co. The trade, conducted on the Easy Trading Connect blockchain prototype, mirrored the paper-based process and included a full set of digitized documents (sales contract, letter of credit, certificates) and automatic data matching, thus avoiding task duplication and manual checks. All participants in the chain experienced significant efficiency improvements.<sup>103</sup>



Covertime

### Chinese blockchain food safety and traceability effort

Jingdong, China's largest e-commerce company (also known as JD), recently announced that it will begin importing billions of dollars worth of food for its Chinese customers and will use technology to promote complete transparency.<sup>104</sup> The retail giant, in collaboration with Walmart, IBM, and Tsinghua University, has launched a blockchain effort to collect data about the safety and provenance of the imported food it intends to sell to its 200 million customers.<sup>105</sup>





## Money with memory motivates better food choices

### From uninformed eaters to incentivized consumers

One of the problems of making affordable nutritious food for lower-income consumers is persuading them to buy it. Lower-income consumers often choose unhealthful food because its long shelf life and inexpensive ingredients make it less expensive than healthier food.<sup>106</sup> Besides being less costly, unhealthful food is often ready to be eaten out of the box or bag, which is important to lower-income consumers who suffer from time poverty as well as financial poverty. To make matters worse, advertising the benefits of nutritious food bears a cost that must be added to the price of the food, which makes it even less likely to be purchased by people on restricted food budgets.

One possible way out of this dilemma is “programmable money”—blockchain-based digital currency that is aware of what it is being spent on and conforms to terms and conditions set by the issuer. Programmable money can work like paper food stamps of the past, but the difference is when it is spent, its usage generates a real-time audit trail that is fully transparent.<sup>107</sup> Programmable money can nudge people to try nutritious foods for the first time and offer incentives to encourage them to buy diverse and healthy food baskets. Programmable money can also give food producers the ability to gain insight into the buying habits of lower-income consumers, and this information can be used to formulate and market more appealing nutritious food for the budget-constrained.

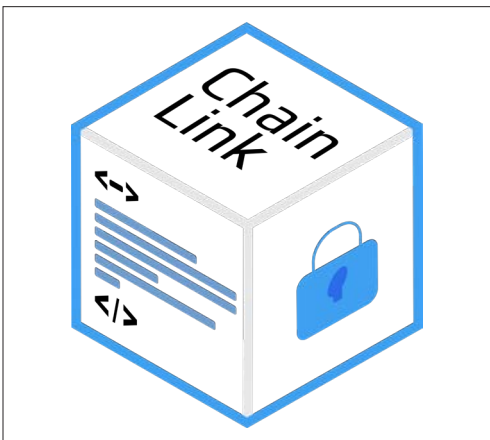
Current food assistance programs for lower-income people usually require the beneficiary to have a bank account. For the world’s two billion unbanked people, programmable money has the advantage that it doesn’t require the spender or recipient to use a bank. Cryptocurrencies can be held, spent, and received by anyone with access to a feature phone or the internet. And smart contracts, computer programs that guarantee that terms and conditions are met before payment is released, eliminate the need for any middlemen. Together, smart contracts and cryptocurrencies can incentivize lower-income consumers to reach for healthy food instead of junk food.



Solidity

### New language for smart contracts

Solidity is a programming language for writing smart contracts that allows organizations to create a tradeable digital token that can be used as a currency, a representation of an asset, a virtual share, or a proof of membership. Food companies can use Solidity to create loyalty tokens and coupons that can be purchased with fiat currency and spent on nutritious food.<sup>108</sup>



ChainLink

### Middleware to link smart contracts with external resources

Producers of food can use smart contracts to guarantee immediate payment upon delivery. For smart contracts to mimic real-world agreements, though, they need secure access to key resources like data feeds, various web APIs, and traditional bank account payments—access not afforded by the blockchain. ChainLink is a blockchain middleware start-up that allows smart contracts to access these key off-chain resources.<sup>109</sup>



MintHealth

### Blockchain-managed tokens to drive healthy behaviors

MintHealth is a global, decentralized health platform that aligns health care stakeholders around the shared goal of patient empowerment and improved clinical outcomes at lower costs. It leverages blockchain technology to empower patients with a self-sovereign health identity—a global, holistic record of their medical data. This platform uses Vidamints, financial incentives to drive healthy behaviors in the form of tokens that are managed and adjudicated through the blockchain.<sup>110</sup>

# Insights

## for Affordable Nutrition

### See Blockchains as the New Supply Chain Middleware

Blockchains can hold many different types of records: inventory management, distribution logs, transactions, purity testing, sales data, and more. Because they are decentralized ledgers that are open to inspection, blockchains can add transparency and efficiency as they replace the current fractured ecosystem of food logistics and lower the cost of ensuring food safety.

### Implement Smart Contracts for Quicker Payments and Instant Settlements

Implementation of self-executing, self-enforcing smart contracts can result in payments that occur immediately after contractual obligations are met. This can lead to a decreased need for credit, and the cost savings can be passed along to consumers in the form of lower prices.

### Use Blockchain to Reduce the Audit Lag

Food logistics currently involve long trails of paper records and proprietary centralized databases. Audits can take days or weeks. Pilot programs have demonstrated that with blockchain technology, full accountings can take place in seconds. When your business no longer has to trace food data, use the savings in time and money to focus on better meeting the needs of lower-income consumers.

### Use Programmable Money to Gain Insight into Lower-Income Consumers

With programmable money, the details of transactions are stored on the blockchain, providing valuable insights for every actor across the supply chain. Buying food becomes a form of information transfer. Use the information to formulate and market food that will appeal to the budget-constrained.

### Don't Forget to Fight Fraud at the Source

Remember that fraudulent information can be added to a blockchain; it just can't be erased. "Blockchains don't guarantee truth," says Nick Szabo, the inventor of smart contracts, "they just preserve truth and lies from later alteration, allowing one to later securely analyze them, and thus be more confident in uncovering the lies. Typical computers are computational etch-a-sketch, while blockchains are computational amber."<sup>11</sup>

“ This is truly a solution for the entire food ecosystem, rather than just a handful of companies. We are already seeing organizations that never before would have interacted or shared data with one another, see the benefits of doing so with blockchain technology and begin to collaborate.”

**Azeem Malik, blockchain business development, IBM<sup>12</sup>**

# Design Principles for an Affordable Nutrition Revolution

Now that you have immersed yourself in the foresight of this report and explored various insights related to the future of affordable nutrition, it is time to take action. As you think about how your business might step up to the challenge of delivering affordable nutrition to lower-income consumers, consider these six design principles for prototyping sustainable, inclusive, and meaningful innovations.

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## **See Systems, Not Symptoms.**

Nutrition is a complex systems-level problem that requires complex systems-level thinking. Innovations to address undernutrition and malnutrition need to appreciate and incorporate the dynamic, multilevel complexity and real-world contexts of this problem in order to create solutions that solve more than just the surface issues.

## **Design for Aspiration, Not Aid.**

Designers need to create innovations that see lower-income markets filled with consumers who have aspirations, not impoverished eaters who need food aid. Treating this segment of the world more like higher-income consumers might enable solutions at a scale that more traditional public health interventions have never been able to achieve.

## **Create Robust Portfolios, Not Silver Bullets.**

No single solution can solve this global problem. Any attempt at developing a single panacea will overlook the inherent complexity of the situation at hand and likely limit solutions dramatically. We need a diverse portfolio that utilizes everything we have, from data to design, in order to create robust solutions that last.

## **Speak to Individual Cultural Contexts, Not Mass Markets.**

Food is an expression of family, tradition, and place. Healthy foods need to be formulated with not only nutrition but also culture in mind. Part of the reason some previous attempts to address nutritional deficiencies have not been successful is that they overlooked the individual cultural contexts in which food is consumed.

## **Fortify with All Nutrients, Not Just Micronutrients.**

Micronutrient fortification is a critical means of improving the nutritional density of foods. However, with a deepened understanding of the interactions between nutrient utilization and the gut microbiome, as well as a proliferation in synthetic biology production tools, opportunities have emerged that go beyond traditional forms of fortification to include macronutrients such as proteins, essential fatty acids, and antioxidants, and to leverage the power of the microbiome to enhance absorption of nutrients.

## **Communicate Long-Term Benefits, Not Just Short-Term Impacts.**

Many of the important benefits of nutritious foods are deferred benefits, which are difficult to communicate but nevertheless should be incorporated into marketing strategies to drive sustained consumption.

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As this report has made clear, taking part in an affordable nutrition revolution can be good business, not just charity. By broadening our imagination, recognizing the range of new opportunities on the horizon, and following the design principles outlined here in early ideation and prototyping phases, we can invent the practical steps necessary to ensure that all people are well nourished. These efforts are foundational for enabling new generations of global citizens to lead healthy, productive lives.

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**Shauna Hargrove**, senior program assistant, Nutrition, Bill & Melinda Gates Foundation

**Bradley Kriet**, research director, Institute for the Future

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