London Technology Club

Future Technology Series: The Future Technology in Nutrition

JUNE 2020

london technology club.com

Foreword on the Future Technology Series: Nutrition

Good nutrition is one of the key pillars of wellness and sustaining a healthy, productive life. Having discovered first-hand the powerful, healing benefits of a plant-based diet, I was inspired to create Farmacy – a place for people who are passionate about taste, provenance and 'living food' recipes for sustainability and human health. It aligns with my passion for natural farming and biodynamics – a sustainable, holistic approach to agriculture that combines the concepts of healing and farming, connecting soil quality with human health.

I'm excited about the future of nutrition. I believe it holds the key to progress for us as individuals (for example, in our challenges with chronic illnesses) as well as a global collective (that is, in facing issues such as inequality, climate change and the compassionate care of animals). As this report notes, food is medicine for us and the world. It is also the foundation on which I built my business.

For me, this is a life-long journey. I am so proud I was able to manifest my learnings and philosophy into my plant-based restaurant, Farmacy – first in London and later also in New York. The menus pay homage to everything that is seasonal, sustainable and nutritious. I once believed London was behind the likes of California. But I now believe the mainstream here as well has shifted to conscious consumption. The progressive health movement around nutrition is here to stay.

This report explores promising technologies that are driving the ongoing evolution towards better taste, affordability and nutrition in our food. These include innovations that can have positive impacts on waste, pollution and the environment, including – potentially – reduced use of antibiotics. I am particularly excited about technology that could help us better understand the provenance of our food and how food can meet our specific, individual needs through personalised nutrition.

Envisioning such a future requires us to acknowledge that drastic changes are needed to today's food systems. While we don't have all the solutions yet, we must recognise that – without change – we face disastrous consequences and suffering in the future. I try wherever possible to spread this message. So it's encouraging to see this report's focus on the future of nutrition and the increasing awareness of its fundamental importance.

My mantra is, 'The KEY in life is to Keep Educating Yourself'. So thank you, LTC, for a fascinating report that helps us all do just that.

Camilla Fayed
Founder of Farmacy

About the London Technology Club

The London Technology Club is an exclusive community of family offices, private and institutional investors, venture capital firms, technology experts and pioneers. The club combines co-investment opportunities, education and relationship-building opportunities in the tech sector under one umbrella and provides access to competitive VC funds with attractive returns.

We organise events with leading technology visionaries, entrepreneurs and investors. A number of prominent international investors are members of our Advisory Board, such as June Felix, CEO of IG Group; Chris Rust, GP of Clear Ventures and ex-partner at Sequoia Capital; and Itzik Parnafes, GP of Battery Ventures.

Future Technology in Nutrition is the second report in our 2020 Future Technology reports series. The first 2020 report – covering property – adds to our previous five published in 2019. All of these are available to download, in full, on the LTC website.

Nutrition is something we should all want to understand and be guided by in our lives, because it's crucial to well-being. Alongside sleep and physical activity, nutrition is a foundation for health – for ourselves and our families.

The right nutrition enables us to maintain a healthy weight, have energy, keep a strong immune system, positively affect our mood and focus – and even delay the effects of aging. Poor nutrition, on the other hand, is a primary driver of chronic diseases. With good, personalised nutrition, many of such diseases are preventable.

Globally, the spectrum of nutrition sees real extremes.

On one end, an estimated 820 million people went hungry in 2018 – the third consecutive year of rising hunger and malnutrition. Moderate to severe food insecurity affects over 2 billion people, according to the UN's *State of Food Security and Nutrition in the World* report[1]. 'We face an immense challenge if we want to achieve our Sustainable Development Goal for Zero Hunger (SDG 3) by the target of 2030'. Those aren't my words... They come from a report signed by leaders of the top UN agencies, including the World Health Organisation, UNICEF and the World Food Programme. Without regular access to nutritious and sufficient food, people across the planet are at greater risk of malnutrition and poor health.

At the other end of the spectrum, obesity is also rising steadily. Globally, one in eight adults (more than 678 million adults) were obese in 2018. This is a challenge particularly for children and adolescents, with over 378 million classified as overweight. This not only sets young people off on the wrong path – it carries the risk of staggering future economic costs.

Based on our current track, it appears we are heading for a challenging if not dire future. However, while writing this report, I have also seen the potential for a much brighter tomorrow – it's led by technological advances enabling modern food solutions to bring down the costs of good nutrition, reduce food insecurity, empower consumers to personalise diets for preventative health, improve food safety, and provide tasty, viable and nutritionally dense food options for billions. The basic challenge – get good, nutritious food in you – sounds simple. But it actually depends on myriad things all working together in just the right ways: food security, trusted supply chains, cultivation, preparation, transportation, storage, cooking, consumption, genomics, the right food combinations for personalised gut health... all of these factors and more come into play.

With the looming threat of accelerating climate change, it is truly exciting to see the potential of food systems to drastically reduce greenhouse gases emissions and to use far fewer resources (land, water, crops, antibiotics etc). This potential could benefit everyone and everything on the planet.

Is it too good to be true? Not at all. And we can ensure it happens. Private capital and investors can be a key accelerating force for good.

LTC member Jim Mellon recently said it best: "With scale and time, you're going to get a vast reduction in the price of plant-based and cell cultured food which will represent nutrition and human health, hygiene and environmental protection. This is the way forward and its happening right now"

In the coming months, we will produce three more reports in our 2020 Future Technology Series, all based around topics our members are passionate about. Watch this space.

1 www.fao.org

Simon Pavitt
London Technology Club
Chief Operating Officer

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01 The Vision Summary

“Each of us now has a world-class nutritionist in our pockets.”

A Future Day in the Life of a Nutritionist

Written by Simon Pavitt, London Technology Club

In our humble opinion, this could easily be a typical day for a nutritionist in the very near future...

Tech has disrupted many things but the disruption I am most happy about is of the cow. We reached ‘peak meat’ in 2021. After that, consumers drastically shifted to analogue meats – partly due to superior taste and nutrition, but also because it no longer made financial sense to buy traditional meat. The plant-based vs meat argument was won. It became the right decision for the environment, for our health and for our wallets.

First it was tofu. Then came Quorn. Then the McVegan. When meat analogues first arrived, they were half as tasty and twice as expensive. But today, getting protein in the form of meat from a single animal cell is widely accepted – even welcomed. The Impossible Whopper has returned to being called the Whopper as all burgers are now made that way. As a nutritonist, I spend all my time working on food-as-software. Rather than wait for evolution, we can make ongoing iterations towards better taste, nutrition and affordability, while also reducing waste, pollution, environmental degradation and antibiotic use. Modern foods and technology let us all find the right nutrition for balanced gut microbiomes, avoiding inflammation and preventing disease. And each of us now has world-class nutritionists in our pockets. I focus on big data and ensuring modern food technologies get into as many hands as possible. Wellness and preventative health are no longer just for the top 1 per cent.

Technology once used by the world’s leading scientists is now in my home. My regular check of biomarkers highlights certain nutritional deficiencies and needs, so my AI-enabled nutrition planner plots out my next few days of food combinations and when it will be best to eat. I wish it didn’t recommend cell-based chicken and shrimp so much, but I understand it’s important for me and my family to follow these recommendations as part of our holistic, preventative health programme. Now and again, though, I ignore these and 3D-print a kobe beef short rib or wagyu sirloin. My kids are obsessed with clean meat nuggets and whey protein-based ice cream!

Around the world, we are moving closer to equitable nutrition. Countries can use bio-reactors to produce what they need locally, so there is less global trade. World leaders continue to make bold nutrition commitments that support a pro-equity agenda, so all people can survive and thrive. It’s been hard for the meat, dairy and pharmaceutical industries. Agricultural land has been freed up for other uses, with no need for livestock and feed production. I wish we had thought earlier about what to do with 485 million acres of former farmland. Incentivising polycropping, rewilding the farmlands and planting a trillion trees anyone?

That reminds me: it’s my wedding anniversary this week. So I have ordered my wife a cell-based leather grown handbag as a gift. My app tells me a Starship delivery robot will be arriving at any moment.

Setting the Scene

Nutrition is widely described as the process of providing or obtaining the food or nourishment needed for health and growth. It is the study of nutrients in food, how the body uses them, and the relationship between diet, health and disease. Better nutrition is linked to improved infant, child and maternal health, stronger immune systems, safer pregnancy and childbirth, lower risk of non-communicable diseases (such as diabetes and cardiovascular disease) and longevity.

There are two types of nutrition: macronutrients and micronutrients. The three main categories of macronutrients include carbohydrates, proteins and fats. The two types of micronutrients are vitamins and minerals. Add fibre and water, and you have the seven elements of nutrition. It is important that everyone consumes these seven nutrients on a daily basis to build their bodies and maintain health.

Here are two good resources to help you understand the basics of nutrition:

nutritionfacts.org
nutrition101.pinto.co

02 The Supply of Nutrition

“We are on the cusp of the deepest, fastest, most consequential disruption in food and agricultural production since the first domestication of plants and animals ten thousand years ago. This is primarily a protein disruption driven by economics.”

RethinkX

Shifting Protein Sources

Proteins are arguably the most important of the three key macronutrients. They are the biomolecules behind an immense number of functions that make life happen.

Proteins provide structure and support for the cell and the body, which makes it possible for the body to move. They are antibodies that help protect against pathogens such as viruses and bacteria. They are messengers that transmit signals to coordinate biological processes between cells, tissues and organs.

By 2040, the world will need to meet the protein needs of over nine billion people. It's urgent that we plan to meet these needs in a healthy, affordable and sustainable way. In nature, many molecules are simply too scarce to find or farm economically – and protein has traditionally been one of them. The go-to source of protein for the western world has been meat, typically from livestock. That's proving increasingly burdensome.

Industrial livestock production has all but reached its limits in terms of scale and efficiency. The cattle industry is resource intensive, requiring enormous quantities of feed crops, land, water and time. According to the 2019 RethinkX Sector Disruption Report, "currently, farmers essentially grow an entire cow before breaking it down into specific products, such as steak, leather or collagen, and the process is nearing its limits in terms of resource efficiency, with little potential to improve costs of production".

Consider these statistics:

- Greenhouse gas (GHG) emissions from livestock account for up to 18 per cent of such emissions globally[1]
- At least one-third of the world's grain harvest is fed to farmed animals[2]

1 The New York Times
2 Proceedings of the National Academy of Sciences

- Animal agriculture is responsible for up to 91 per cent of Amazon deforestation[3]
- On average, it takes around 6kg of plant protein to produce 1kg of animal protein[4]
- Grain-fed livestock wastes 83 per cent of the calories they consume; it's a highly inefficient conversion of energy[5]
- It takes 4kg of wild fish as feed to produce 1kg of farmed salmon[6]
- Antibiotic usage in agriculture accounts for 80% of worldwide consumption[7]

In 2018, USDA figures showed that US domestic production of meat hit a record high of more than 100 billion pounds. That translates to a staggering number of animals grown for food: around 30 million beef cows in the US and more than 20 million pigs in Iowa alone. Globally, the meat industry had an estimated value of $945 billion in 2018[8]. Our reliance on meat for protein is firmly entrenched in our food systems, economies and cultures. Global meat consumption is expected to grow 70% by 2050.

However, recent developments in food-related technologies promise to address the ecological and practical challenges of feeding the world's growing human population. The recent pandemic has also highlighted that food can be a source of vulnerability for our societies. Globalised food trade means multiple opportunities for contamination. The key lies with finding compelling incentives and alternatives for governments, business and consumers. For the UK, it has an enormous trade deficit (£24.3bn from food) that it would love to reduce.

3 World Bank
4 The American Journal of Clinical Nutrition
5 UNEP, 2009
6 fishcount.org.uk
7 who.int
8 Statista

Disrupting the Cow (and others)

> "Unlike the cow, we get better at making meat every single day."
>
> Pat Brown, CEO, Impossible Foods

The way the food and agriculture industry is supplying protein is changing rapidly, driven by technology advances. Here we outline three innovations – cultivated meats, precision fermentation and 3D food printing – as modern alternative sources of protein and ways to reduce our consumption of 'traditional' meat.

Cultivated meats

Cultivated meat promises a one-for-one substitution: replace meat from the slaughter of animals. In simplistic terms, cultivated meat requires a biopsy taken from any species of choice – be it a cow, pig, fish, chicken or shrimp. Stem cells are then isolated from the sample, which are subsequently proliferated – grown – in bioreactors, to create sufficient biomass. The cells are fed nutrients, and growth factors, causes the cells to double. A change in conditions then causes the cells to differentiate – turn in to – muscle, fat and connective tissue. A 2.5 mL sample of cells can turn into 3,500 kgs of meat in less than 40 days.[1]

1 www.gfi.org

Some believe consumers will feel more comfortable with cultivated meat, as it is animal meat, than with some of the alternatives described next. Cultivated meat is targeting the mass market of omnivores, whereas plant-based meat will also be the minority market – the plant-based meat market accounts for less than 1% of total meat production.

California-based Memphis Meats is cultivating cells into meat by "feeding them their favourite nutrients" – a process they call 'Essential Nutrition'. The company's goal is to preserve the benefits of conventional meat while making products that are healthier, safer and more nutritious. Founded by Uma Valeti and Nicholas Genovese in 2015, Memphis Meats debuted its first synthetic meatball in 2016 and followed up with the world's first cell-cultured chicken and duck in 2017. The company's goal is to feed 10 billion people by 2050. The firm is backed by investors like SoftBank Group, Temasek, Norwest and Threshold Ventures, as well as by food industry leaders Cargill and Tyson Foods, Bill Gates and Richard Branson. It raised US$161m Series B round in January 2020 – the first company in the sector to raise a Series B round.

Greater efficiency

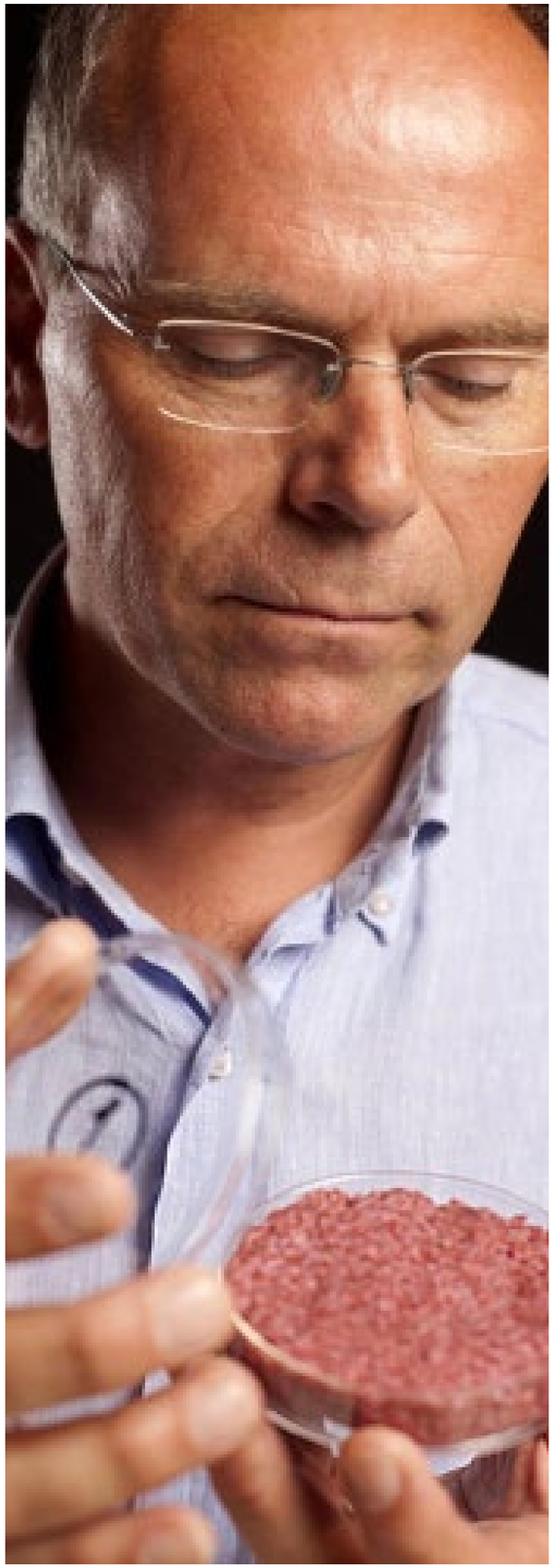
The world's first 'lab-grown burger' was unveiled to the world in 2013 by Mark Post. It was a research project funded by Sergey Brin. At the time, that burger cost €250,000 to make.

Mark is now CSO at Mosa Meat, a Dutch food technology company founded in 2016, headquartered in Maastricht that's creating production methods for cultured meat.

The company has since brought the price down closer to €9 and plans to bring its product to market in 2023 By 2024, it envisions seeing Mosa Meat products on supermarket shelves and winning over consumers with the benefits of cultured meat. The key is that the company's process requires only a small number of animals to provide the sample cells (for example, one cell sample can create up to 10,000 kilograms of cultivated meat).

> *"Our estimates suggest that, at that rate, we would only need 150 cows to satisfy the world's current meat demand."*
>
> ***Professor Mark Post,***
> ***Chief Scientific Officer, Mosa Meat***

Mosa Meat has improved its meat's protein content, changing culture conditions to allow the cells to produce more myoglobin. Myoglobin, which gives meat its red colour, is a protein made by muscle cells and provides oxygen transport within the cell. It is also the source of iron in meat and likely adds to its taste. Mosa Meat and others (for example Meatable) have focused on ground-beef products first. Ground meat is the most significant and ubiquitous beef product, representing 40–60 per cent of the output of a cow by volume.



Clean seafood

BlueNalu's mission is to be the global leader in cellular aquaculture. That involves manufacturing 'clean' seafood by growing cells of certain species of seafood in bioreactors for human consumption. Its goal is to provide consumers with great tasting, healthy, safe and trusted products that support the sustainability and diversity of the world's oceans. There will be no risk of microplastics, or contaminant metals such as mercury in the products, which are common unwanted additions to ocean-caught fish. According to FAO, 96% of fish stocks are exploited or depleted, to limit this, the only solution is to reduce our reliance on the world's oceans to meet our needs. In a series A preferred fundraiser completed in December 2019, the company raised $20 million from new and existing shareholders. The company is targeting a small-scale commercial launch of its seafood products in late 2021 in the US.

Challenges ahead

Firstly, the technology challenge is developing an efficient process whereby all stem cells are converted in to the desired components of meat, requiring limited inputs and high levels of media recycling.

Secondly, scaling. JUST, more commonly known for its mungbean based liquid egg, also has a cultivated meat division. JUST claims it has 1,000L bioreactors producing cultivated meat at present. No other company has achieved scale this high. Their bioprocess will need to be scaled up to 20,000L or greater, to meet global meat demand.

Others like Israeli-based Future Meat Technologies are focused not on consumers but on food producers. Using new bioreactor designs, the company aims to provide the hardware and cell lines that would allow anyone to become a manufacturer of cultivated meat. They are looking to build a technology platform intended to be species agnostic- currently for avian, beef, pork and lamb production lines. The focus on a B2B approach means they aim to convert slaughterhouses, meat processors and meat packing facilities.

Founder Yaakov Nahmias' goal? "To be the largest company you've never heard of. I want to make a product that is more sustainable and more cost-efficient, and is better for everybody."

The company's strategy is to sell cultivated meats through established protein brands, anticipating that customers will be more likely to try the product that way. It looks to work with big meat companies that have established supply chains, and that can also provide facilities and retail shelf space. That will help cultivated meat scale quickly to reach price parity with traditional beef, pork and chicken.

Regulatory challenges in some markets might be a factor in delaying sales of cultured meats and clean seafood. Currently there are no approved products on the market and regulatory approval typically takes 18-24 months around the world. Due to the government's support of cellular agriculture, Singapore is touted as a launch location for some. The Singapore government has established its 30 by 30 programme: to produce at least 30% of its food locally by 2030. Given Singapore does not have any arable land, the only way to achieve this is through cultivated meat bioprocesses.

In September 2017, China announced a $300 million deal to import lab-grown meat from three Israel-based companies — SuperMeat, Future Meat Technologies and Meat the Future. It's part of a broader plan in China to decrease the country's conventional meat consumption by 50 per cent. China's diet is becoming increasingly westernised, partly due to the trend for healthier leaner meat. This is seeing more chinese eat chicken than ever before. Partly also due to the outbreak of African swine fever, which decimated its local pig populations. Cultivated pork could certainly fill this void, and avoid disease outbreaks amongst livestock in the future.

Precision Fermentation

Fermentation has been around since ancient times. It makes food more digestible, and also can improve taste, texture, flavour and aroma. Most important of all, fermented foods – things like beer, wine, bread, cheese, koji and miso – can be preserved and stored for long periods of time. Add precision biology (the ability to genetically engineer microorganisms to produce desired ingredients) the combination of biology and information technology – and the result is we can now design and program microorganisms to produce any products we want using fermentation – including animal proteins.

PF is the key to unlocking the potential for plant-based products and other food products like cultivated meat. PF will allow microorganisms to produce an infinite number of these ingredients to enhance and improve plant-based products. PF is also likely to underpin other new technologies, such as the production of cheap growth factors for cultivatedmeat.

What's next?

Next up for disruption are the dairy proteins found in cows milk. Rather than being extracted from milk, which accounts for just 3% of milk's composition, these proteins are being produced directly and efficiently using microorganisms. . These proteins, including casein and whey, are being reconsistuted with plant-based materials to create animal-free dairy products, including ice cream.

Perfect Day, based in Berkeley, California, has GRAS ("generally recognised as safe") designation for its recombinant β-lactoglobulin whey protein, which is currently constituted into ice cream products. We will see a full set of other regulatory approved products on the horizon globally: casein, whey proteins and dairy fatty acids.

It's a complete reversal of conventional food production – the opposite of breaking down a cow into constituent components with vast amounts of energy, land and water wasted along the way, and then processing those into the desired end products. Where single-molecule food building blocks were traditionally the hardest and most expensive to produce, in the new system, they are the easiest and cheapest. Crucially, the single-protein molecules made using modern fermentation production techniques will be superior – purer and more consistent in quality – to those taken from the cow.

Dairy under threat

As protein production switches to alternative methods, the 35 per cent of the milk market used for ingredients will disappear rapidly. For some traditional dairy companies, the disappearance of those revenues could well spell bankruptcy, it already has for Borden and Dean Foods in the US.

But the rest of the milk protein market could also soon be at risk, as production of dairy products like cheese, yogurt and ice cream also moves to cheaper, better PF-based proteins. The disruption of whey proteins will be a key catalyst in this process. Today, regulated dairy producers get compensation for whey, whether or not there is a market for this protein. Whey is a byproduct of cheese production that brings incremental revenues to large cheese manufacturers. As PF whey disrupts cow whey, these manufacturers will join the small cheesemakers who already lack access to the dry whey market and will lose the income they now earn through disposing of whey.

This spells opportunity for new companies using PF instead. This includes LegenDairy Foods, which is developing delicious and ethical dairy from milk proteins produced with fermentation rather than from cows. The firm's biotechnology uses yeast to express milk proteins, focused on producing casein protein first, a key constiuent in mozzarella cheese. The proteins will be reconsituted with plant-based fats to create stretchy mozzarella for the mass market.

There's also Clara Foods, which utilises PF to create egg-free egg proteins, to be incorporated into baking products, food and beverage ingredients and nutritional supplements. At least 30 per cent of eggs today end up as ingredients in other food products. By disrupting the egg protein ingredient market, the modern food industry could push the primary egg production industry into a financial tailspin.

Ultimately, the revolution coming would be massive. All animal-derived products will be disrupted, whether they come from a cow, pig, chicken or fish.

3D Printing

3D food printing is the process of manufacturing food products through additive manufacturing. Most commonly, food-grade syringes contain edible printing material, which is then deposited layer by layer using a food-grade nozzle. The most-advanced 3D food printers include preloaded recipes and also allow users to remotely design food products via computer, phone or IoT device. Food can be customised by shape, colour, texture, flavor or nutrition, making the technology useful for everything from mass consumption to healthcare and space exploration.

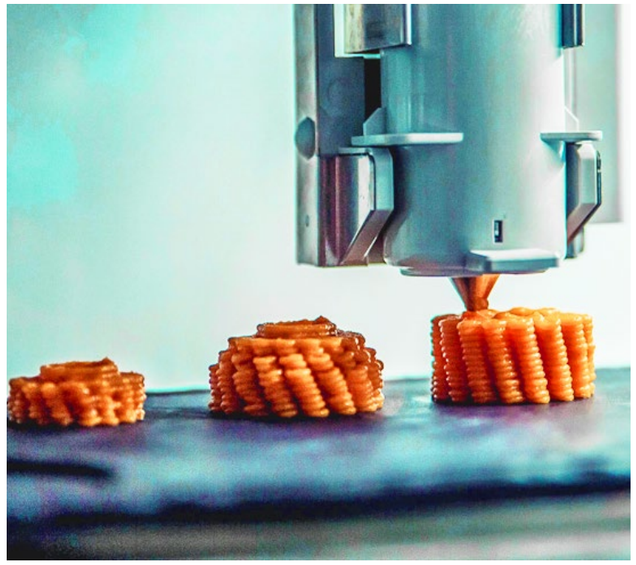
> *"Someone could have a precision fermentation vat located in their garage or basement and pull plans from the global database to 3D-print their own top-quality steak."*
>
> ***Jennifer Elizabeth Brunton,***
> ***Author, This is Capitalism***

We'll likely be able to access printed foods (like meat) in supermarkets first, followed by restaurants (for printed flavors, etc.) and, finally, our own homes (for personalised printed nutrition). Picture a printer sitting next to your microwave. To set up the printer, you input your health and nutrition profile, determined by blood testing. After that, all you have to do is load it with bio-ink, select the programming for the meal you'd like and soon enough… Voila! Dinner is served.

The three main types of 3D food printing use nozzles, powdery

material and lasers[1]. Many systems mix and match these approaches:

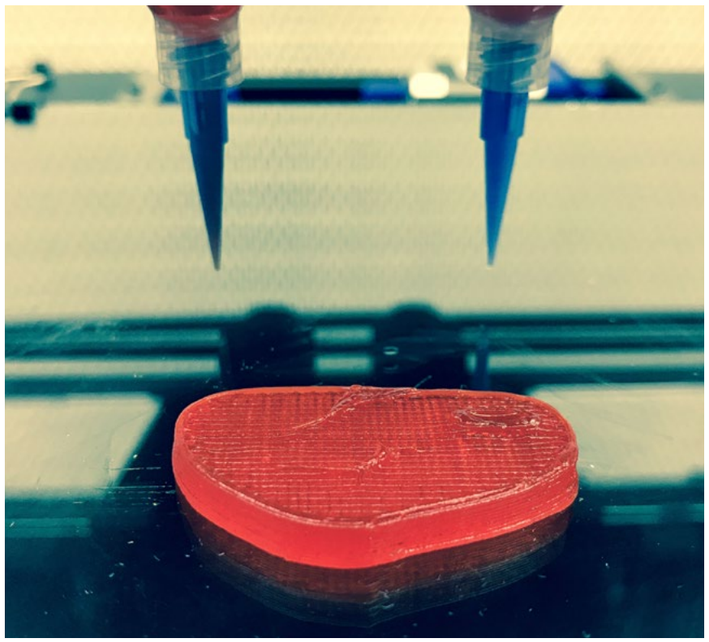
- The 3D Systems ChefJet crystalises thin layers of fine-grained sugar into virtually any geometric configuration.
- Natural Foods' Choc Edge dispenses chocolate from syringes in beautiful, melty patterns.
- The Foodini uses fresh ingredients loaded intostainless-steel capsules to prepare a surprisingly wide array of dishes. Its latest model isn't a soup-to-nuts solution — it prints only raw doughs, which then must be cooked as normal — but the printer can partially make pizza, filled pasta, quiche and even brownies.



3D printing companies are being backed by investors like Bill Gates, Richard Branson, Tyson and Cargill.

Who's leading the way?

In 2012 Modern Meadow won $350,000 in backing from Peter Thiel, one of Silicon Valley's most prominent venture capitalists, a PayPal co-founder and an early Facebook investor.



The company's flagship product is Zoa™, a branded materials platform constructed from fermentation produced collagen protein, with no reliance on animal-based agriculture. Zoa™ is inspired by traditional materials such as leather, and reduces petrochemical use and animal dependency in making materials.

Modern Meadow was started in 2011[2] by CEO and co-Founder Andras Forgacs, formerly of Organovo, a company that uses 3D printing of human tissue for medical use[3]. The company has raised approximately $54 million from investors including Thiel, Singapore's Temasek and Horizon Ventures, the private investment fund of the Hong Kong billionaire, Li Ka-shing. The company was recognised by the World Economic Forum as a 2018 Technology Pioneer.

Novameat, a Spanish startup, can print a plant-based steak and mimic the texture and appearance of real meat. Texture is probably the biggest novelty, according to the CEO: "I was able to generate something that had the same texture as meat, I was able to create micro fibres that resembled not just a hamburger or a meatball but had the same texture as muscular tissue."

1 disruptionhub.com
2 wikipedia.org
3 wikipedia.org

Novameat's product is entirely plant-based, made out of protein powder from peas and seaweed. However, unlike other plant-based alternatives available today, it comes in the form of a steak, not a ground-meat product.

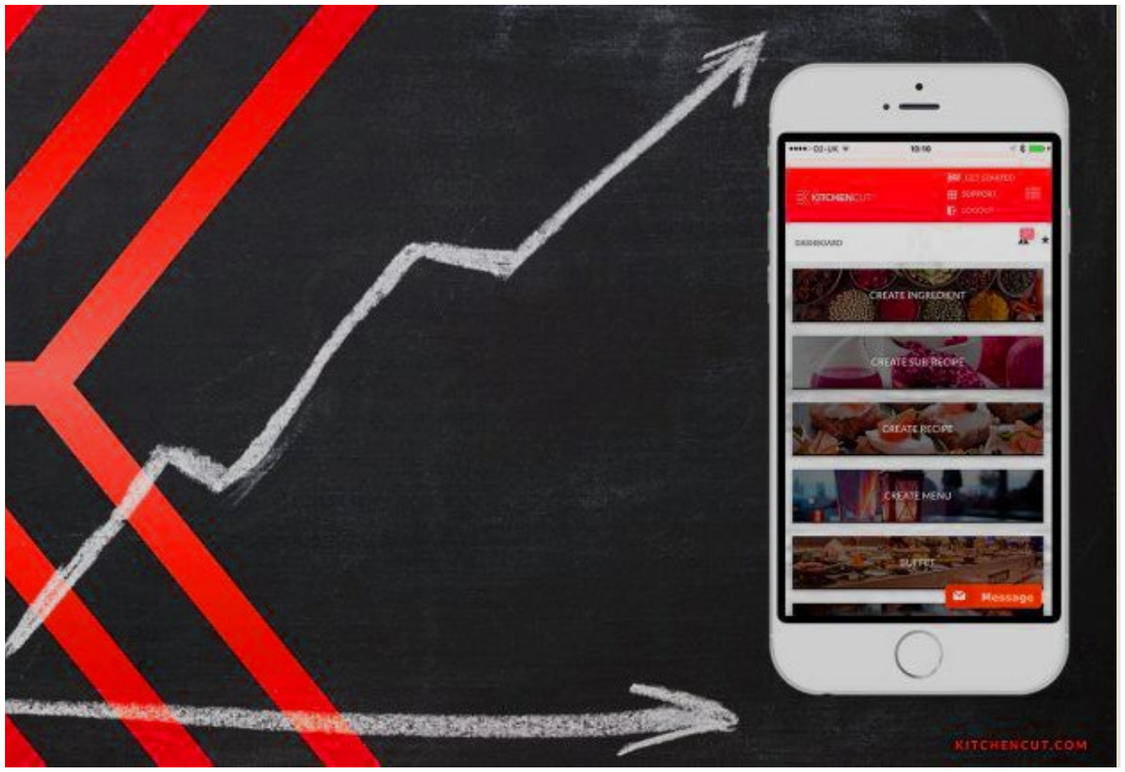
Redefine Meat (also known as Jet-Eat) is based in Israel. The startup is working on a technology that will produce plant-based meat alternatives – steaks, roasts and stews – from natural and sustainable ingredients. The company uses proprietary 3D printing technology, digital modelling and plant-based food formulations to deliver a new category of meat.

BeeHex has found wild success in a place you might not expect: outer space. BeeHex's 3D printer is designed to provide astronauts with fresh, specially tailored nutrition rather than freeze-dried beef. Even better, it can print pizza — astronauts' most highly requested meal. This personalisation in nutrition and flavor is where

printing's true opportunities lie: for NASA, the US military (with which BeeHex recently contracted) and people in general.

Obstacles ahead

For 3D-printed food, the main obstacles are ability to scale cheaply, safety, reliability and speed. Devices like the recently announced Carbon3D can fabricate a mind-boggling number of objects in minutes, but that level of advancement hasn't yet trickled down to food printers. The most common designs require successive layers of ingredient to cool, leading to exceedingly long wait times for some foods. So for now, these devices are currently not practical – a 'simple' tomato alone would likely require tens of millions of different ingredient cartridges.



Food-as-Software

Advances like cultivated meat, PF and 3D food printing are now being combined with an entirely new model of production: food-as-software. In food-as-software, individual molecules engineered by scientists are uploaded to databases; these essentially become molecular cookbooks that food engineers anywhere in the world can use to design food products just like software developers design apps. This model ensures constant iteration: products improve rapidly, with each version cheaper and better than the last. It also ensures a completely decentralised production system that is much more stable and resilient than industrial animal agriculture. Fermentation farms can be located in or close to towns and cities. There is no reliance on biological evolution.

This means diets could not only be dramatically improved but tailored to individual requirements without the need for behavioural change – people could eat as many hamburgers as they want without the side effects. By improving access to a more balanced and nutritious diet, modern production methods will bring better nutrition to more people. In the developing world, especially in areas where malnutrition is a problem, access to a consistent source of inexpensive protein will have a hugely positive impact on nutrition and overall health.

Plant-based meat

> *"Over the next few years, the best pork, the best chicken, the best fish, cheese, eggs the world has ever seen will be made directly from plants"*
>
> ***Pat Brown, CEO and founder, Impossible Foods.***

Plant-based meat is made entirely from plant ingredients, but is produced so it resembles traditional, animal-derived meat products like burgers, steaks, hot dogs or jerky. Historically, soy has been the most popular main ingredient for plant-based meat. Recently, though, companies have begun successfully using other ingredients like wheat, yellow peas and coconut. These new ingredients have become more prominent thanks to technology advances enabling superior functionality, including more meat-like flavour profiles, textures and appearances.

Many companies have now entered the mainstream market, becoming recognisable brands like Impossible Foods, with its Impossible Burger, or Beyond Meat.

Impossible Foods

Impossible Foods researches animal products at the molecular level, then selects protein and nutrients from plants to recreate the experience and nutrition of meat products.

The company's signature product, the Impossible Burger, was launched in July 2016 after years of research and development. In 2019, Burger King released the Impossible Whopper – the meatless Whopper.

The burger includes an ingredient found in the root nodules of soybeans, called leghemoglobin, which is a protein that is chemically bound to a non-protein molecule called heme. Heme – an iron-containing molecule – gives leghemoglobin its blood-red color, just as it does for blood and red meat. Impossible uses PF to genetically engineer yeast to produce this heme molecule, differentiating its plant-based products from its competitors.

Impossible Foods says its burger requires 95 per cent less land and 74 per cent less water, and emits about 87 per cent less greenhouse gas than a ground-beef burger from cows. The plant-based burger has more protein, less total fat and fewer calories than a similar-sized hamburger patty made with beef – and no cholesterol. To date, Impossible Foods has raised $1.2 billion over 12 rounds of funding from the likes of Google Ventures, Horizon Ventures, Khosla Ventures, Temasek Holdings, Sailing Capital and Bill Gates.

> "We think of it as meat made a better way... Meat today basically is made using prehistoric technology, using animals to turn plants into this very special category of food... But to your typical consumer... the value proposition of meat has nothing to do with its coming from an animal,"

says Impossible Foods CEO and founder Pat Brown.

The key is genetic modification and the technology that allows Impossible Foods scientists to understand the consequences of changes at a molecular and physiological level.

> With our ever-improving understanding of the genetic basis for important traits in plants and animals, and powerful tools for understanding the consequences of changes at both a molecular and physiological level, we can actually be much more conservative and precise with the modifications we introduce,"

adds Brown.

Beyond Meat

> *"More and more consumers are beginning to understand the biggest choice they make in terms of impact on the climate is protein."*
>
> ***Ethan Brown, CEO, Beyond Meat***

"The future of protein": that's the mantra plastered across Beyond Meat's R&D lab in El Segundo, California. Beyond Meat uses technology to – through heating, cooling, pressure and mixing – build imitation meat directly from plant materials. It's red colouring, is provided from a low tech approach of using beetroot extract.

The future for these companies lies with bringing the cost of their products below that of meat, surpassing meat's flavour and providing equivalent or better nutrition.

Food companies investing in disruption

Companies such as Cargill and Tyson Foods are beginning to invest in these kinds of disruptive food products. Indeed, in the five years leading up to 2018, $17.1 billion (including the $12.5 billion acquisition of WhiteWave by Danone in 2017) was invested in plant-based food, with $720 million invested in 2018 alone. A further $73.3 million was invested in cultivated meat companies. In early 2019, the plant-based meat firm Beyond Meat went public with an initial public offering price of $25 – shares soared 550 per cent in the first month of trading.

Other companies focused on meat alternatives include Nestle's plant-based Sweet Earth Foods, Tyson Foods, Beyond the Butcher and Hungry Planet.

Nuggets: Rebellyous Foods

Rebellyous Foods partnered with brilliant scientific minds to craft protein-packed nuggets, patties and tenders – they're covered in a crunchy cornmeal coating to cook just like breaded chicken products. These arrive ready to heat and eat, so they're ideal for schools, hospitals, corporate cafeterias or restaurants. The company raised $6 million in its series A funding round from the likes of Agronomics and Vulcan Capital, the investment arm of late Microsoft co-founder Paul Allen. Originally named Seattle Food Tech, the firm became Rebellyous Foods as part of its move to consumer-facing brands and products.

Fish: Good Catch Foods

Pennsylvania-based startup Good Catch Foods, which raised $32million in series B funding in Januaey 2020, develops vegan tuna, crab cakes and fish patties. The company has also partnered with Bumble Bee, a 30 year old, leading seafood company in the US, to help it scale production and support its products' placement in Whole Foods, FreshDirect and Thrive Market stores. The company's seafood look-alikes are made from lentils, chickpeas, fava beans and other legumes.

Impact from modern foods

Modelling by RethinkX predicts a huge impact for such modern foods. Beyond the reduced cost and demand for animal-derived tissue, these foods can also lower waste and use of land, water, energy and antibiotics:

- At current prices, revenues of the US beef and dairy industries and their suppliers, which today exceed $400 billion, will decline by at least 50 per cent by 2030, and by nearly 90 per cent by 2035; other livestock and commercial fisheries will follow a similar trajectory.

- At current prices, feed production revenues for cattle will fall by at least 50 per cent, from $60 billion in 2018 to less than $30 billion in 2030.

- At current prices, revenues for fertilisers, pesticides and seeds will also fall by 50 per cent as fewer feed grain crops are needed to feed fewer dairy and beef cattle.

- The number of slaughterhouses and meat and dairy processors will drop by more than 50 per cent.

- By 2035, 60 per cent of the land currently used for livestock and feed production will be freed for other uses. That's 485 million acres – 13 times the size of Iowa.

- Farmland values will collapse by 40–80 per cent, with varying outcomes for different regions and individual farms. New food production systems will affect the existing value chain in different ways.

By 2030, the area used for cattle pasture, rangeland and feed cropland will decline by about 50 per cent, freeing up about 300 million acres of land. This will rise to 450 million acres by 2035, portending a rapid collapse in the value of land. The farming industry has a lot to lose.

Finally, as the World Health Organisation notes, meat production accounts for 80 per cent of antibiotics use in some parts of the world. In an interview with UBS, Michael Greger – a medical doctor, well-respected founder of Nutritionfacts.org and author of How Not to Die and How Not to Diet – explained the positive impact of a plant-based diet: "The most significant advantage not found on nutritional charts is food safety. Plant-based food has no issues with intestinal bugs, such as E. coli or Salmonella, as the food never had intestines… The scale and speed of modern animal farming have led to heavy usage of antibiotics critical to human medicine. If demand for meat continues to grow, we could see more rampant usage of antibiotics and more antibiotic-resistant bacteria entering the food chain."

The impact on the pharmaceutical sector could also be profound if the demand for antibiotics for animal farming significantly drops.

AI meets supply chains

The organic supply chain and produce suppliers have long followed regulations for temperature

controls, cargo tracking, and supply and demand planning software, which allows produce to be tracked from farm to table or – in case of a recall – back to the source. But there are new safety concerns for supply chain organisations handling meat alternatives that combine multiple plant-based ingredients. Considerations include how to store and process meat alternatives, how to treat each ingredient in the product and, most important, how to determine temperature controls or the source of contamination.

Applications like the Internet of Things (IoT), automation and blockchain are all being touted as ways to curb food safety issues. The FDA, in conjunction with major food brands and technology companies, has piloted blockchain and AI programmes to better track drugs and food products. Technology clearly has the potential to help the industry comply with food safety regulations while meeting customer demands for plant-based alternatives and organic options.

Thinking ahead

The Jeremy Coller Foundation are pioneers in this field. The main driver is the desire to move away from intensive livestock production. The foundation established the FAIRR Initiative: a collaborative investor network that raises awareness of the material environmental, social and governance (ESG) risks and opportunities brought about by intensive animal agriculture. FAIRR helps investors identify and prioritise these factors through cutting-edge research that investors can then integrate into active stewardship and decision making. It's the first initiative to encourage the world's largest food companies to take an evidence-based global approach to diversifying protein sources away from overreliance on animal proteins.

The FAIRR Initiative says intensive animal production poses material risks to the global financial system and hinders sustainable development.

In its latest phase of engagement, the initiative has asked 25 global food retailers and brand manufacturers to publicly disclose information about their plans for protein portfolios with lower impacts and more sustainable sources. This includes plant-based and/or alternative proteins to support a dietary transition to prevent the global climate from warming by more than 1.5 degrees C.

Fresh momentum in COVID-19

Around the world, meat processing plants are at the centre of many recent COVID-19 outbreaks. Meat industry workers have been disproportionately impacted by the pandemic, with over 20,000 workers in the US alone contracting the virus to date. Slaughterhouses and processing facilities have been forced to close or reduce capacity in response to labour shortages and social distancing requirements. This pattern of disruption reveals key bottlenecks in animal protein supply chains, and their inherent fragility to external shocks.

Across Europe and the US, regulatory conversations are focusing on several core themes: breaking up industry consolidation, implementing moratoriums on factory farms, banning live exports, limiting antibiotic use and overhauling biosecurity containment and surveillance practices. According to FAIRR:

> "In the medium term, a shift to more sustainable plant-based proteins offers resilience where animal protein production has failed. Plant-based proteins are more efficient to produce, can be scaled up or down to meet market demand in a matter of days and don't have the disease risks associated with livestock."

Our take on the future – the next 10 years and beyond

By Laura Turner of Agronomics

Agronomics

> *"Only recently have viable technologies emerged with the potential to displace animal husbandry. These solutions include the replication, simulation or substitution of animal protein and are driving the formation of an entirely new industry."*
>
> ***Agronomics***

Agronomics is an investment play into the clean-meat sector that is set to disrupt the $7.3 trillion global meat, poultry and seafood market. The chairman is Richard Reed, co-founder of Innocent Drinks, Europe's largest and most environmentally sustainable juice company, which successfully exited to Coca-Cola in 2013 for $600 million. Reed is also co-founder of Jamjar Investments, a consumer goods VC with early-stage investments in category-defining companies such as Deliveroo, Blue Bottle Coffee, Graze.com and Tails.com. Jim Mellon, the prolific entrepreneur and investor is a non-executive director.

The Agronomics portfolio includes BlueNalu (cultivated seafood), Meatable (cultivated pork and beef), Rebellyous Foods (plant-based chicken analogues), the LIVEKINDLY company the only company in the plant-based food sector that is owning and operating the entire value chain of production). The LIVEKINDLY company most recently announced it had acquired the Swedish plant-based brand Oumph!, joining other brands Likemeat and Fry's Family Food in its portfolio. PURIS, the largest North American pea protein supplier has also taken an equity stake from LIVEKINDLY.

Also in the portfolio is VitroLabs. VitroLabs is a lab-grown leather company, the only company globally that is utilising cell culture, to grow genuine leather hides, without the slaughter of animals. VitroLabs has developed the world's first fully scalable tissue engineering platform to achieve this. Large fashion houses LVMH and Kering have made public commitments to achieving substantial environmental targets: Kering intends to reduce its environmental footprint by 40% by 2025. Achieving this means reducing the reliance on animals to create fashion goods. Lab-grown leather is a viable solution.

If the population does indeed expand to nearly 10 billion by 2050, then there is already a sector that can meet the 70 per cent increase in global protein demand – and completely overhaul and optimise the food we know today.

This food sector has proactively harnessed cell culture, fermentation and gene editing tools to generate superior animal products that are nutritionally valuable – and can be produced efficiently and cleanly – with a limited impact on the environment and without livestock.

Novel food flavours, textures and experiences are on the horizon. The success of future food will be driven by the creation of new sensory experiences beyond what current food items can deliver. Chefs will have a vital role in showcasing these novel ingredients.

Cultivated meat products will be on the market in the next couple of years, in the form of small scale launches. Adoption will be led by health-conscious, environmentally aware and curious consumers, but mainstream adoption will follow with accessibility of products at lower costs.

Consumer trends

The lines between food categories will become increasingly blurred to account for ‘animal-free’ meat, dairy and seafood products. Plant-based imitation meat and dairy products will have to compete with cultivated meat and PF based products to retain customers – the utilisation of novel food science approaches will be necessary to improve the taste and texture of their products. While the plant-based alternative trend will continue, the absence of defensible intellectual property (IP) for some consumer brands will limit their long-term success.

Convenience underpins consumer choice. Even when consumers desire healthy, sustainable and low-cost choices, these products must be accessible in a consumer’s lifestyle – accessible in local grocery stores and supermarkets, or via easy purchase online, at Ocado for instance. Once the future foods are available in these avenues, they will become the daily normality.

Sustainable food and clean labels will become mainstream. Transparency of protein production will be led by the cultivated meat companies, putting pressure on conventional meat producers. Slaughterhouses will close, the number of livestock on the planet will decrease and antibiotic usage globally will decline. Consumer choice of meat will slowly become to be between only grass-fed, organic raised animals or cultivated meat. Intensive farming will be a distant memory.

Commercialisation

We are at the crossroads of culinary art and food science: the first regulatory approved cultivated meat products will be available towards the end of 2021. Chefs will be able to work with these products as new ‘tools’ for cooking, and be able to generate entirely new culinary experiences in prestigious restaurants around the world.

Meat production will be decentralised and become local to the country, region or city. Pilot cultivated meat facilities will be established in jurisdictions where products are approved for consumption. Full-scale facilities will follow producing meat in such an efficient manner, that it produces 97% less greenhouse gas emissions, requires 96% less land and 98% less water than traditional meat production. In the UK, this will reduce imports, narrowing the £24.3 billion trade gap. Chlorinated chicken will not be a concern. Expect similar impacts elsewhere too; this will bring new limits to the global trade of food.

Three companies with unique technologies

Tropic Biosciences uses CRISPR and TALEN gene-editing tools to develop high-performing commercial tropical crops, including coffee and banana. Building on these tools, the company also uses their GEiGS™ (Gene Editing induced Gene Silencing) technology to edit existing RNAi genes and direct their silencing towards new targets, including insects, viruses, fungi or even a plant’s own genes. This ultimately will enable a robust set of crop protections and crop enhancements for the global agricultural industry.

University of Cambridge spinout Bit Bio, which recently raised $41.5 million from Foresite Capital, BlueYard Capital, Arch Venture Partners and Richard Klausner, has a proprietary cell differentiation technology called Opti-Ox. This allows for the rapid and efficient reprogramming of cells. Meatable licenses this technology from Bit Bio for use in making pork and beef meat in an efficient manner.

Solar Foods will lead the way in creating food as part of a circular carbon economy. It will do this with its proprietary gas fermentation technology, which uses electricity to hydrolyse water into hydrogen and oxygen. Combined with carbon captured from CO2 in the air, these elements are used as the feedstocks to grow a unicellular organism.

03 The Demand for Nutrition

“Let food be thy medicine, and medicine be thy food.”

Hippocrates

The previous section focused on companies using technology to reimagine the key aspects for micronutrition: protein production and supply. The other side of the economic model is demand fuelled by changing consumer needs and expectations around nutrition.

We see three major future trends that will impact consumer demand:

1. The recent shift to more plant-based foods and the potential long-term shift to modern foods (cell-based, PF, 3D-printed foods etc.) covered in section 2

Changes in consumer preferences can be rapid. A Nielsen survey found that 39 per cent of Americans are trying to eat more plant-based foods[1]. The market for meat substitutes is expected to be $6.4 billion by 2023[2]. To provide some context, total organic dairy and egg sales in 2018 amounted to $6.5 billion.

We will explore two more in this section:

2. The move towards Personalised Nutrition

3. The shift in consumer mindset on the role of food and nutrition from 'form' to 'function'

1 nielsen.com
2 Research and Markets Global Meat Substitutes 2018-2023

Personalised Nutrition

Personalisation has been adopted by many industries. From footwear, TV content, marketing and advertising to hotels and furniture, advances in technology, data and analytics allow more tailored experiences across moments, channels and products.

And personalisation has informed healthy eating for a long time: "Since the dawn of time, we've been asking what foods are right for us. We've done high carb/low carb, high fat/low fat… one day eggs are good, the next they are bad. Despite all the diets out there, the reality is that there's one prevailing question: 'What foods are right for me?'" says Neil Grimmer, founder of Habit.

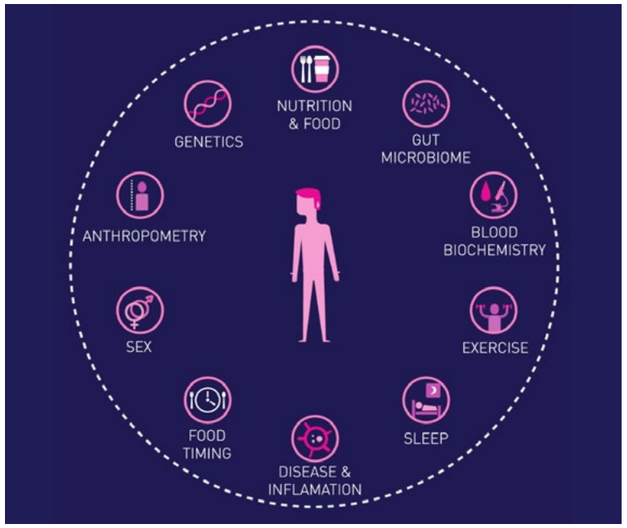
Despite this, the idea of personalised nutrition – where information from an individual is used to develop healthy, science-based nutritional solutions for that particular person – has yet to go mainstream. However, we are entering the age of personalised nutrition, where science and technology can dictate what food and nutrition is right for us – not only for weight management but, more importantly, to manage our overall health and wellness.

The parallels with precision/personalised medicine are clear: both are new frontiers for healthcare, combining genomics, big data analytics and population health. Both are an emerging approach for disease treatment and prevention that takes into account individual variability in genes, environment and lifestyle for each person.

The personalised nutrition market is estimated to reach upwards of $11.5 billion by 2025[1]. And UBS predicts the personalised nutrition industry could be propelled to $65 billion by 2040.

Following are examples of companies building consumer-facing platforms to provide personalised nutrition solutions.

1 axiommrc.com



Zoe and the PREDICT Programme

Nutritional science company ZOE has been working with world-leading experts in the areas of nutrition, epidemiology, microbiology and data science to better understand how and why we all respond to food differently. Professor Tim Spector, professor of genetic epidemiology and director of the TwinsUK registry at King's College, London, is one of the founders.

'Years in the making', the PREDICT programme is the world's largest ongoing nutritional science study. By using artificial intelligence to compare thousands of people's results, ZOE can generate meal plans that reduce dietary inflammation that can lead to ill health and weight gain. In June 2020, initial results were published in the journal Nature, including;

- Your nutritional responses are unique, which means that there is no one 'right' way to eat.
- The relationship between the number of calories consumed and nutritional response is not straightforward – the adage of 'calories in, calories out' no longer works.
- Your genes don't determine how your metabolism works – the programme found that even identical twins, who share all their genes, can respond differently to the same foods.
- It's not just what you eat, but how and when you eat that matters – the research suggests that what you eat accounts for less than 25 per cent of your nutritional response. The form your food takes, when you eat, food sequence, mood and food combinations all play a role in determining how you break down and use food.
- Your microbiome influences your nutritional responses, health and weight – the good news is that the microbiome can be altered by changing what you eat, offering a positive way for everyone to improve their gut health and weight.

ZOE is developing a consumer test kit and precision nutrition app to give you the ability to reduce dietary inflammation and achieve your healthiest weight. These recommendations will be personalised to your unique biology and microbiome rather than focusing on just food alone.

According to ZOE, "the ability to dissect the integrated, inter-related multidirectional pathways with large-scale, high-resolution data is what makes precision nutrition achievable".

Gini DNA-based app

Canadian startup Gini is a personalised and actionable mobile app to help users take care of their health and nutritional needs based on their DNA. Consumers upload their raw DNA data from 23andMe or Ancestry DNA to start learning about their nutritional

needs. In essence, Gini is a nutrition assistant powered by the user's daily life, biometrics and genetic code.

Gini breaks down complex health nutrition gene relationships, functions as a guide for an individual's micro or macronutrient needs, and helps identify the optimal food sources for their genetic profile.

Habit Lab test values based plans

Habit provides personalised nutrition plans based on consumers' self-reported lab test values. Viome (more about them later) acquired Habit from Campbell's Soup in 2019. The two were seen as complementary, as Viome was making personalised recommendations based on a person's microbiome, while Habit develops nutritional recommendations based on an individual's biology, metabolism and personal goals.

LSee – Biomarkers-based nutrition

French startup LSee provides personalised nutrition recommendations based on blood biomarkers, which provide information on the metabolic or physiological efficiency at the moment of measuring. They show the impact of changes to lifestyle, including exercise and nutrition. The system uses a metabolic tracker device and a mobile application that analyses specific biomarkers with a single drop of blood. The results are transferred to the smartphone via Bluetooth and the application then shows tailored nutrition and sports recommendations based on a person's own metabolism.

Pinto – personal food label app and website

New York-based Pinto's app and website are based on the idea of personal food labels. Rather than providing the same generic information to everyone, Pinto adapts its guidance according to the needs and goals of each individual end user, helping them navigate nutrition on their own terms. When you look up food or scan a barcode, the info that matters most for your unique needs is displayed.

Pinto has built a comprehensive nutritional database of 100,000 food items from Whole Foods, Kroger and the 200 most popular fast-food and fast-casual restaurants in the US – in all, comprising the top 85 per cent of everything Americans eat. Pinto works with Whole Foods Market to power personalisation, product search and deep product information across inventories.

Spoon Guru

UK-based Spoon Guru has a pioneering smart food search and discovery app to help consumers find appropriate products and recipes for food preferences. The app features a powerful barcode scanner for immediate assessment of a product's suitability. Spoon Guru claims to be the world's leading safe, accurate and reliable dietary management solution.

By combining world-leading expertise in nutrition and dietetics with state-of-the-art machine learning and research science, Spoon Guru delivers relevant food choices that exactly fit consumers' individual food preferences and metabolic needs.

The company was founded in 2015 by Marcus Regan, Tim Stripf and Tim Allen, motivated by friends' and relatives' frustrations in finding the foods that were right for them. Labels are often hard to read in supermarkets. Spoon Guru's free-to-use business model is based on licensing its technology to food businesses and retailers around the world. With offices in London and Los Angeles, the company has been described as Netflix for food curation.

Spoon Guru's algorithms process hundreds of thousands of products and attributes daily to ensure the data is always up to date. Consumer packaged goods (CPG) companies are able to use Spoon Guru's data to show the concentration of nutrients in their product offerings, as well as gaps and opportunities to grow.

Through the combination of AI, machine learning and nutritional expertise, Spoon Guru enables grocery partners to create increasingly personalised shopping experiences.

The company is helping retailers such as Tesco in the UK (the driving force behind its online tag system), Albert Heijn in the Netherlands, and Woolworths in Australia and New Zealand, to cater for shoppers' distinct dietary needs. Other major retail partners include Walmart, Whole Foods and Amazon Fresh. The company has received funding from NJF Capital[2].

With 64 per cent of the world's population now actively excluding certain foodstuffs from their diet, the future is about the food you don't need as much as about the nutrition you do need, and about being matched to the right functional food choices. The company has been especially busy during the COVID-19 pandemic, winning praise for helping users quickly locate products rich in immune-boosting ingredients.

"Our AI machine learning can reliably and safely process and classify hundreds of thousands of products to help shoppers in seconds. We know the use of our technology can help support people choosing the right foods during the current health crisis," says Marcus Stripf.

Summarising the current states of personalised nutrition (PN), Robert W. Beardall MD, MPH, FACPM, has said: "PN is an emergent clinical field and discipline with tremendous potential to address chronic disease and optimise human health, performance and healthspan. PN is delineated by two major elements: PN science and data and PN guidance and therapeutics. Continued research and the development of innovative technology solutions will lead to increasingly individualised nutrition guidance, products and services. Enhanced education and training will equip a generation of practitioners who can apply personalised models of care to better support the health and wellbeing of individuals and communities."

Beardall has written an in-depth report about personalised nutrition for the London Technology Club – please see the appendix to read his report in full.

2 crunchbase.com

The Consumer: From Form to Function

Consumers are shifting from food buying decisions based primarily on form (e.g. water or coffee) to decisions based on the product's functional benefits (e.g. protein = function). Functionality as a benefit is moving beyond the traditional world of vitamins and supplements to play a key role in food and beverage, while the supplement space evolves to reflect food-as-medicine ideals. If personalised nutrition companies continue to empower consumers with increased knowledge about their specific needs, with their own nutritionist via the smartphone in their pocket, it follows that people will start to desire value-added food and beverage products.

Industry analysts predict that the global functional food and beverage market will reach $275 billion by 2025.

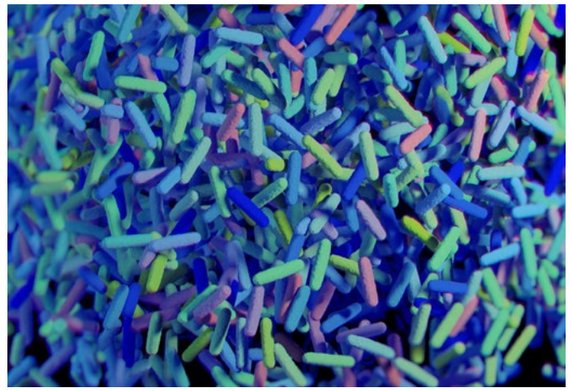
Weight concerns are the top reason consumers make dietary changes[1]. 'High in nutrients/healthy components' is the number-one way consumers define a healthy food, followed by 'free from artificial ingredients'. Eighty per cent are concerned about the nutritional content of their food, with 29 per cent very concerned[2].

Two-thirds (65 per cent) of adults look for foods and beverages that have added vitamins/minerals, while 63 per cent try to add more fibre, and 60 per cent seek more protein[3]. This follows the notion that, with personalised nutrition, consumers will be looking for foods to serve a specific function.

The term 'functional foods' is used to describe foods and drinks enriched with particular nutrients or substances that have the potential to boost health beyond their basic nutritional value. A functional ingredient can be defined as a dietary ingredient that affects its host in a targeted manner to exert positive effects that justify certain health claims[4].

Functional foods have also been starting to appear on the shelves due to increased consumer awareness around the microbiome.

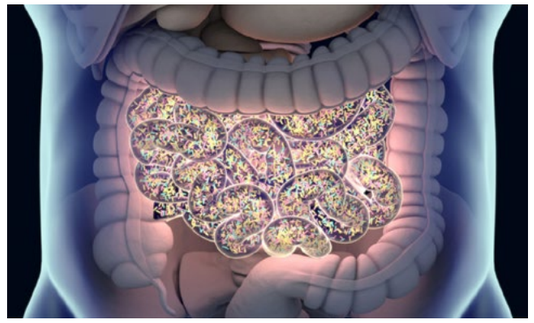
1 IFIC 2017
2 FMI 2017
3 Hartman 2017
4 nutrition.org.uk



Functional foods and the microbiome

Humans are mostly microbes; our bodies contain more than 100 trillion of them. Microbes outnumber our human cells 10 to one. The majority live in our gut, particularly in the large intestine. The microbiome is the genetic material of all the microbes – bacteria, fungi, protozoa and viruses – that live on and inside the human body. The number of genes in all the microbes in one person's microbiome is 200 times the number of genes in the human genome.

The bacteria in the microbiome helps digest our food, regulates our immune system and protects against other bacteria that cause disease. They also produce vitamins, including B12, thiamine, riboflavin and Vitamin K, which is needed for blood coagulation. The microbiome was not generally recognised to exist until the late 1990s, and there is still much



to understand around its role in human health and disease. The working thesis is that we have the Gut-Brain Axis. The bugs in our stomachs have a direct impact on neurological health. Much of our decision making and emotional responses originate deep in the walls of our digestive system. Preserving the health of our digestive system therefore affects both physical and mental health.

The key is understanding whether our microbiomes are turning the foods we consume into helpful nutrients or harmful toxins. As we learn more about microbiomes, coupled with personalised nutrition, we're discovering the exciting potential – for both consumers and food companies – to have food and nutrition to proactively manage and modify our gut balance, defects and mood. Conscious consumers can move to more proactive and preventative nutrition to decrease the likelihood of health problems, rather than reacting only when problems occur.

For consumers, preserving a healthy gut microbiome is becoming a way to derive health benefits from food. Examples of foods that can provide the function of health benefits around gut health include probiotics, prebiotics, stanols and sterols. Probiotics are the most well-known parts of the microbiome. They are are the 'good' bacteria that live in our guts and promote healthy digestion and bolster immunity. Prebiotics are naturally occurring carbohydrates that feed them. Only by having those two components in balance can the gut begin to thrive. The use of labelling and products described as 'probiotic' is already mainstream on food packaging and marketing.

Probiotics as a drinkable solution

PERKii, a $4 million foodtech startup from the University of Queensland, has also invented PROGEL, a strong coating for probiotics as they travel through the digestive tract. The 'encapsulation' procedure allows the bacteria to reach the gut with more of their defensive properties intact. Probiotics have to survive not only the journey inside us, but also the manufacture of food products, in sufficient numbers to make a difference to our gut. PERKii's technology is patented as the world's first probiotic water and comes in a range of natural fruit flavours.

Based on the discovery that bad bacteria and bad fungus work together to create digestive imbalance, BIOHM Health produces drinks that marry the function of the two. The formula focuses on the role played by fungi in good digestive health, combining the two substances to corrode digestive plaque. Historically, digestive plaque has always proven difficult to break down, frequently forming harmful film across the lining of the gut that protects against bad bacteria and fungi.

Stool sample-based solutions

Day Two and Viome are acknowledged as leaders in this field. Both start from stool samples and offer personalised action plans based on the results. The underlying technology harnesses cutting-edge metatranscriptomic (the science of gene expression of microbes) sequencing tools designed to monitor pathway activity. The premise is that blood sugar level has a strong influence on individual food response. Day Two profiles the composition and diversity of a customer's gut microbiome at a genetic level. Its patent-pending algorithm is based on the customer's biometrics, stool sample and health questionnaire, which together yield a unique nutrition profile. The app then provides personalisation to achieve blood-sugar balance.
Viome describes itself as a mission-driven systems biology company aiming to help individuals improve their health. In June 2020, it launched its Health Intelligence Service to provide new insights into how a person's cellular, mitochondrial, immune system and gut health – as well as their stress response and biological age – change over time. This is the only service that measures how human, mitochondrial and microbial genes are expressed in the body. It translates these expressions into actionable health markers, which can be improved by following Viome's personalised nutrition recommendations, developed with the help of advanced artificial intelligence.

Despite having no background in science or medicine, Viome's billionaire founder Najeev Jain has so far raised $75 million from renowned investors including Marc Benioff, Bold Capital (Peter Diamandis and Sergey Young) and Khosla Ventures. British pharma giant GSK also struck a royalty deal with Viome in November 2019 to use its tech to develop microbiome-derived vaccines.

"We finally have the technology available to be able to digitise the human body at a molecular level and analyse system-level biochemical activities," said Naveen Jain, CEO of Viome. "This deep understanding allows us to recommend to each individual as to why they should eat certain foods, and why they should avoid certain foods based on their own individual biology, with the goal to prevent and reverse chronic disease.

> *"This is bringing us one step closer to our mission to make chronic disease a matter of choice and not a matter of bad luck."*

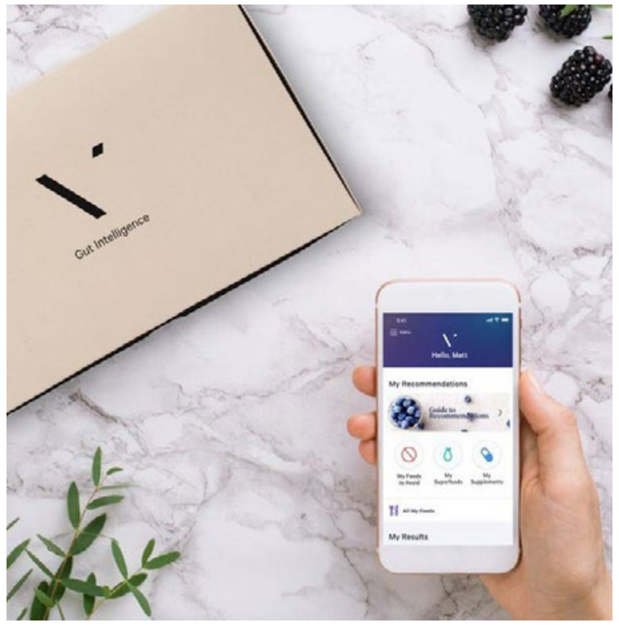
So far, over 125,000 customers have taken Viome's first Gut Intelligence test. For the likes of Viome, the race is to gather enough gut microbiomes to be able to identify patterns via artificial intelligence. Viome wants to get to two million gut biomes as quickly as possible.

Prebiotics as medicine

Sequoia-backed Pendulum Therapeutics is revolutionising medicine through the development of live synbiotics (combinations of bacterial strains and prebiotics) for two diseases most commonly associated with gut malfunction: diabetes and irritable bowel syndrome. Its software maps the gut microbiome and identifies the function of particular microbes. By comparing the results of healthy people to those with a metabolic disorder, the company is able to identify the bacteria lacking in each case. The end 'synbiotic' product, Pendulum Glucose Control, is described as the first 'medical food' of its kind in the treatment against Type 2 diabetes. In May 2019, Pendulum Therapeutics announced $35 million in series B funding led by Sequoia Capital.

We predict the future of messaging around gut health, microbiome and nutrition will be about reducing inflammation and increasing mainstream understanding of biomarkers. We are already seeing the messaging that no two humans process food in the exact same way: "Whilst bananas may be a guilt-free snack for some, for others they have the effect of a triple fudge chocolate cake".

Foods that might be beneficial for some prove inflammatory for others. To stay healthy in the long run, we all need to build a detailed picture of our own individual microbiome.



Neuronutrition and supplements

Put simply, neuronutrition refers to the process of feeding your brain for optimal performance. Again, it is about considering the function of food and nutrition. Getting the right nutrients to support neurological functions and processes can improve the health of your brain, strengthen memory, restore cognitive function after a brain injury, maintain or even optimise cognitive function as you age, and improve personal productivity. Nourishing your brain with the right nutrients can even help prevent age-related cognitive decline and related disease like Alzheim-

er's. We are realising that nourishing the mind can have positive effects on our mood and cognition. The future is choosing a lunch based on what you have to do that afternoon – perhaps the function is to be alert and fuel concentration to finish some complex mental task vs an afternoon of switching one's brain off.

Your brain is the first part of your body to suffer when you have chronically inflammation from poor nutrition or stress. Once your brain's mitochondria become inflamed, they have a harder time generating any kind of energy. This reduced ability to produce energy now can lead to the development of chronic diseases later.

This is where neuronutrition comes in. It works by providing an optimal supply of substances that ensure optimal functioning of the neurons and the brain, while protecting it from damage caused by free-radical formation, lack of oxygen, lack of glucose or neurotoxic substances.

Neuronutrition works to reduce both inflammation in the brain and oxidative stress, while restoring energy production to dysfunctional mitochondria. It relies partially on the specific nutrients you provide the brain from certain foods and dietary changes (e.g. wild salmon, avocados, coconut oil, blueberries and broccoli).

According to Dan Murray-Serter, co-founder of Heights, the human potential company focused on brain health and mental wellness through all-natural smart supplements: "A growing field of scientific and public interest is neuronutrition or the impact that our diet has on our mental health and performance. It is well known that people living with mental health problems such as depression often present with nutritional deficiencies if tested. We also know that many drug treatments for depression and anxiety work more effectively when taken alongside nutritional supplements such as B vitamins and fish or algae (vegan) oils, particularly DHA Omega 3."

We also know that people with early-stage demen-

tia and memory problems can experience measurable benefits in mental performance and even brain structure, from nutritional supplementation.

Elsewhere, companies able to link nutrition to discernible benefits beyond aesthetics are likely to do well over the next few years, particularly among women. Conversations around women's health and wellness are no longer solely appearance focused. They now concentrate more on holistic mental and physical wellbeing.

Due to a lack of funding into mental health optimisation, we don't have good data on how the general public, with day-to-day fluctuations in mental performance or mood, might benefit from nutritional interventions or supplementation. That said, when we pull together data showing dietary patterns and observe the chronically low intake of some of the nutrients most notably associated with mental health, we can predict that many people would benefit from daily supplementation. The key is to successfully combine behavioural change with coaching and psychological aspects for sustainable lifestyle change.

Biohacking

The noticeable lack of guidance for health optimisation coming from conventional scientific and medical research has contributed to the rise of the 'biohacking' community. Focused on health optimisation and longevity, biohackers are growing in number and – while their methods and ideas might be controversial in conventional healthcare circles – they reflect the growing public interest in our ability to control what

we often consider to be unavoidable side-effects of modern life, such as stress, poor sleep and poor mental performance.

With robust medical research linking nutrition and mental health, the demonstrable benefits of tech in healthcare, and a growing dissatisfaction with the perception that suboptimal mental health is inevitable, a perfect storm has been created for innovators in the neuronutrition space.

Food reformatted via meal replacement drinks

The shift in consumers' mindset from 'food for form' to 'food for function' is most visible in the rapid rise of meal replacements or 'non-traditional meals'. These are nutritional liquids that provide the same macronutrients, vitamins and minerals as a regular balanced meal. The nutritional balance is done for you and portions are pre-measured, ready to drink consumable on the go.

Leading the way are two companies – Huel and Soylent – both of which target busy consumers. Their meteoric rise has been fuelled by their direct-to-consumer (D2C) models to make life even more convenient (including a subscription-based model).

In the UK, Huel launched in 2015 with a flavoured meal shake. It entered the US in 2017 and there passed $10 million and $19 milion in sales, respectively, in its first two years. It raised $26 million in funding from Highland Europe and has now sold more than 100 million meals to over 100 countries.

Huel's main selling point: it is a nutritionally complete food providing you with all 27 essential vitamins and minerals, protein, essential fats, carbs, fibre and phytonutrients. The company is keen not be seen as a meal replacement; it compares its liquid product to soup.

> "We believe that there are two types of food: functional food and entertainment food".

"Huel is never going to be the solution for a Saturday night out with friends as a social occasion, but there are many times during the week that you need nutrition and convenience. You need the balance between those two categories," says Julian Hearn, founder and CMO of Huel.

In the US, Soylent leads the pack with over $71 million in disclosed funding from investors that include Andreessen Horowitz, Lerer Hippeau Ventures and Google Ventures. Its drink product has run into some problems, including a ban in Canada (lifted only recently after two years), where regulators said it did not meet all of the country's specific requirements for meal-replacement products. Soylent focuses mostly on a D2C model, but it is also available in some stores across the US. It launched in the UK in late 2018.

Others hot on the heels are San Francisco-based Ample Foods, which raised £2 million in seed funding in 2018 and an angel round in 2019, and Feed, a French powder-based meal replacement company that has raised over $21 million.

With the success of meal replacement drinks aimed at busy mainstream consumers, more niche customers might be targeted in the future with even more tailored nutritional functions. Some of these aim to help kids get the nutrition they need. Others target breastfeeding mothers with banana flowers to help support healthy lactation. There are also meal replacement drinks that promise positive aging solutions for the over-55 crowd with essential added nutrients such as protein and calcium.

04 Nutrition Extremes

"This double burden of malnutrition – two sides of one crisis – has vast health, economic and environmental implications, affecting every country of the world in some form"

UN 2020 Global Nutrition Report

Global nutrition reporting from the WHO, UNICEF and the World Bank makes for bleak reading. The 2020 Global Nutrition Report reveals significant inequalities in nutrition outcomes within countries and populations. We are far from achieving nutrition equity. We must start from the agreement that everyone deserves access to healthy, affordable food and quality nutrition care.

As the reports states: "Poor diet is the leading cause of mortality and morbidity worldwide, exceeding the burdens attributable to many other major global health challenges. The resulting global malnutrition crisis includes hunger and undernutrition – mainly stunting, wasting, underweight and micronutrient deficiencies – and diet-related non-communicable diseases (NCDs) – mainly overweight, obesity, diabetes, cardiovascular disease and cancer. This double burden of malnutrition – two sides of one crisis – has vast health, economic and environmental implications, affecting every country of the world in some form."

Currently, one out of every nine people – 820 million worldwide – are hungry or undernourished, with numbers rising since 2015, especially in Africa, West Asia and Latin America. Around 113 million people across 53 countries experience acute hunger as a result of conflict and food insecurity, climate shocks and economic turbulence. At the same time, more than one-third of the world's adult population is overweight or obese[1].

1 globalnutritionreport.org

The Obesity Challenge

The Foresight obesity report, which looks at ways that the Government can tackle the obesity problem over the next 40 years, has projected that by 2050 60% of the UK population could be obese.

Currently, no country in the world is on course to meet obesity targets, male or female. We are off course. Obesity is no longer a disease that only affects the more developed, affluent countries. It is now a worldwide public health problem, affecting all age and socio-economic groups

For business, the estimated economic impact amounts to $2 trillion annually – roughly 2.8 per cent of the global GDP. The burden on insurance premiums goes without saying. Good nutrition as part of a healthy lifestyle is key to a person overcoming obesity. In short, this is a challenge ripe for digital disruption. Here are some of the solutions technology has to offer:

Visual logging

For many of us, the easiest way to lose weight is to watch it. That is why digital food loggers are increasingly popular. The act of taking a visual mental note of what we are eating increases mindfulness and awareness of our likes and dislikes, what we crave and which situations lead us to those foods.

Award-winning mobile app Noom merges insight from be-

havioural psychologists, nutritionists and personal trainers. It focuses on making tangible, enjoyable lifestyle shifts rather than on pushing more depressing dieting. The app, which costs a minimum of $49 per month, provides the following:

- Analysis of your shopping trolley by searching a database or scanning barcodes
- Logging of exercise, weight, blood pressure and blood sugar
- In-app 1:1 health coaching during business hours
- Interactive articles and quizzes – an algorithm collates your answers and presents you with your own individual dietary plan

While Noom is not the only fitness coach on the market, it is one of the fastest growing – as well as the third most Googled diet for two years in a row. Since its inception, Noom has attracted $144.7 million in investment from the likes of Sequoia Capital, Samsung Ventures, WhatsApp co-creator Jan Koum, DoorDash cofounder Tony Xu and Oscar Health cofounder Scooter Braun.

Smartplate and Foodvisor recognise food items and dimensions on your plate and provide a detailed report in a matter of seconds. Foodvisor can also sync users' daily step count and physical activities from the default iOS Health app. Once the information is ready, Foodvisor then presents you with the total calorific information and assesses it according to your goals. The startup's app is available on iOS and Android in French, English, German and Spanish for a monthly subscription fee of $5–10.

Healthy snacking

What does the future hold for comfort food? The future is guilt free and green, thanks to millennial-driven shifts. And it's a desire that big CPG players have been quick to exploit, as reflected in all the 'better for you' offerings rolled out by PepsiCo, Coca Cola and Kellogg's.

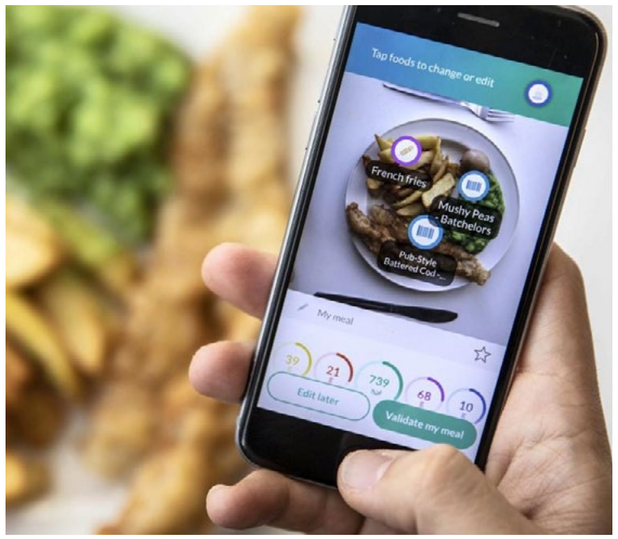
Mushroom fermentation

This year, Kellogg's investment arm Eighteen94 Capital joined forces with Tyson Ventures and Bunge to provide $39 million in series D funding for MycoTechnology™. Hailed as the world's first organic bitter blocker, the award-winning US mushroom fermentation platform is focused on promoting plant proteins, reducing sugar and fixing flavour defects.

Their base ingredient is simple: a digestible, non-GMO, shitaki fungi protein powder that can be added to sodas, teas, coffee and bread. Buoyed by early success, Myco upgraded production facilities in 2018 to bolster output and reach wider communities. Myco's centre uses large fermentation tanks that allow products to be grown vertically and reduce land use. The company also employs water and energy recapturing systems to ensure sustainability.

Edible insects

For a twist on plant proteins, why not try edible insects? Two billion people around the world eat them, according to the UN's Food and Agriculture Organisation. While the idea is still typically taboo in Western countries, bugs and insects nonetheless have growing investor appeal.



ExoProducts, under the new umbrella of Aspire Food Group, capitalises on cricket farming, which produces 100 times less greenhouse gas than beef cow production, and produces higher proportions of protein than beef or chicken, according to experts. Production is also more efficient, given the significantly lower amount of food required to raise crickets.

To make eating bugs more palatable, other manufacturers are using insects to create alternative ingredients, such as protein powders, flour and gummy bears from beetles, grasshoppers, bees and spiders. If insect farming catches on, it could eventually rival plant-based protein as another healthy and sustainable option.

Biofortification

The trend towards more nutrient-dense snacks leads to biofortification. Over two billion people worldwide suffer from 'hidden hunger', or micronutrient deficiencies. It might sound, on the face of it, like a developing world phenomenon, but the absence of key vitamins and minerals in our food chains has long been linked to obesity, with taste being the industry's priority. The result is those affected thirst for foods that are high in fat and sugar.

Micronutrients most lacking globally are iron, iodine and vitamin A, zinc and vitamin B-12. With that in mind, the biofortification industry has seen significant investment over the past decade in fields ranging from sugar conversion processing to dietary fibres, as well as in much broader fields like vertical farming and food as software.

Dietary fibres

Dietary fibres received strong backing last year following two separate reviews from the UK Lancet and the WHO. The papers endorsed fibres' influence on satiation, reduced cholesterol and increased lifespan. Market research promptly recorded a 23 per cent rise in European fibre-based product launches.

Further afield, Japanese Taiyo launched 'Sunfiber Cola', the first sugar-free, functional cola range with added satiation-boosting Indian guar bean fibres. Backed by particularly stringent US FDA regulation, Taiyo expanded its products in early 2020 by combining its Sunfiber ingredients with a probiotic. It also launched a new dual-action women's health product. According to Taiyo's experts, the company's approach to weight management targets maximum mineral absorption in the gut, thus normalising blood sugar levels.

Sugar reduction

Israel-based DouxMatok is a prominent player facilitating sugar reduction. Its approach is to engineer sugar molecules and coat them onto fortified carriers – tasteless minerals, fibres and proteins that directly target taste buds. Upon contact with receptors, their carriers are better equipped to instil the sugar for longer periods of time. With normal sugar, 80 per cent goes directly to the stomach.

Fresh from $22 million raised in a series B funding last year, DouxMatok is now focusing on expansion into Europe and North America. The funding round was led by Singapore-based fund BlueRed Partners

and includes strategic investors: Germany's Südzucker AG, the largest European sugar company; Royal DSM, a global leader in science-based nutrition, health and sustainable living; and Singha Ventures, a corporate venture fund of Singha Corporation, one of Thailand's largest food and beverage conglomerates.

Crop level

Micronutrient deficiency is exacerbated the world over by the problem of crop and soil degradation. Rapid urbanisation complicates things further, with inner cities and remote communities routinely cut off from the most natural, nutritionally superior produce. It is a problem that vertical farming entrepreneurs aim to solve.

Despite concerns over production and labour costs, there is growing attention from notable investors. High-profile deals include New Jersey-based AeroFarms, raising $ 100 million in 2019 to expand its aeroponic growing facilities, and Californian startup Plenty, raising $200 million in 2017 in a funding round led by SoftBank Vision Fund, along with backers including Jeff Bezos and Alphabet chairman Eric Schmidt. Equally noteworthy is Iron Ox, whose fully autonomous facilities champion hydroponics and are run by robots.

Aerofarms is now set for international expansion following a $100 million investment from the Abu Dhabi Investment Office's Agtech Incentive Programme. Plans are for a new 90,000 sq ft complex, dedicated to R&D and commercialisation of local crops through technology that uses 95 per cent less water than traditional farming and zero pesticides. The facility will include an advanced organoleptic research and precision phenotyping lab, advanced seed breeding centre, phytochemical analysis lab, machine vision and learning lab, and a robotics, automation and drones lab. The aim is to grow plants with specific in-demand nutritional profiles.

Vertical farming feeds into the much broader revolution described in section 2 in 'food-as-software'. This is where foods are engineered by scientists at a molecular level with that information then uploaded to databases that are accessible to food designers and app owners around the world. The innovation comes at a time when rising populations and an increasing global middle class place pressure on existing production. Emerging markets are driving this growth: China, in particular, is the world's largest consumer of meat, with protein consumption expected to grow by around 4 per cent annually. These new systems also aim to shield markets from volume and price volatility due to the changes in seasons, weather, drought, disease and other natural, economic and political factors. Geography will no longer offer any competitive advantage or disadvantage for delivering good nutrition to everyone.

Childhood Obesity

Perhaps most striking with regards to obesity is the state of childhood obesity. It matters because gut health plays such a large role in social skills, behaviour and academic performance, not to mention the risks involved with lifelong obesity.

Writing for the LTC Report, Dr Sophie Niedermaier-Patramani, MD, FCRPH, founder of Little Tummy, said: "The tracks for a life with obesity are paved out in early childhood as a majority of obese children continue to be so in adulthood[1]." According to a UK government report, one in three children who leave primary school are overweight, and the numbers have slowly been rising over past years[2] Worldwide, 1 in 6 children is overweight or obese, which added up to 380 million affected children in 2018[3] – more than the total population of the US.

There are many causes of childhood obesity, so a multifaceted response is needed. One factor is our genes, which cannot be changed as of yet. However, lack of physical activity and bad sleep – among other causes of obesity – can be influenced.

While increased screen time and the associated physical inactivity are considered contributing factors, technology can also help tackle this problem. For the past decade, governmental institutions have supported technology companies developing innovative solutions aimed at preventing childhood obesity. The PRECIOUS project is one of them. It uses virtual models and gamification to induce healthy behaviour[4]. Other projects are trying to support parents and children in increasing physical activity and access to information.

However, the main contributing factor to childhood obesity is the consumption of too many calorie-dense foods from an early age. The first 1,000 days of a child's life are the time when healthy habits are established and cemented. Nutritional sciences, enhanced by the right technology, can help parents establish healthy habits from early on and thus prevent childhood obesity right from the start:

First, parents and caretakers need to be educated on how to make healthier choices. The Change4Life Food Scanner is an app developed by researchers for Public Health England. It lets parents scan barcodes and indicates the amount of sugar a product contains. It also provides suggestions for healthier swaps and incentivises healthy behaviour with rewards.

Upon scanning the barcode of a product, the nutritional label comes to life. Sugar content is shown by the amount of sugar cubes. Different products can

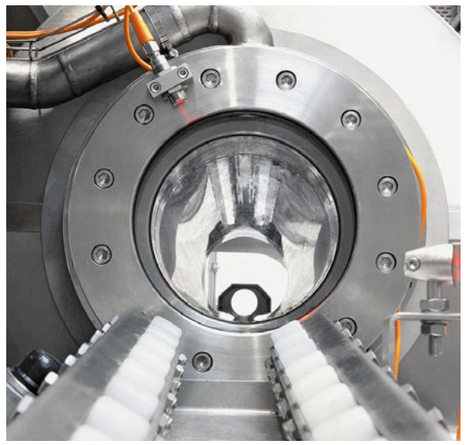
1 Childhood obesity as a predictor of morbidity in adulthood: a systematic review and meta-analysis. Llewellyn A, Simmonds M, Owen CG, Woolacott N. 1, 2016, Obes Rev, Vol. 17, pp. 1467-7881.
2 gov.uk
3 who.int
4 thepreciousproject.eu

be compared and the app will show healthier alternatives to a sugary snack.

Another way technology can foster the reduction of childhood obesity is by changing how recipes for children's meals are developed. Large databases can help optimise the nutritional value of meals, for example, by matching ingredients that complement one another's functions. Choosing ingredients depending on their nutritional value rather than on taste will help in designing healthier recipes. In the near future, these databases will help companies personalise their customers' meals. This will need to start with the first foods a child receives. Data on things such as breastfeeding, the mother's nutrition and amount of formula feeding – as well as activity levels and the child's developmental phase – will be taken into consideration when planning the child's menu of first foods and variety of meals over the first year of life. This will help to meet the child's individual nutritional requirements and support healthy development.

Finally, innovative processing methods can help make ready-made foods healthier and take the pressure off parents who don't have time to prepare meals themselves. One of these technologies is High-Pressure Pasteurisation (HPP), which uses high levels of isostatic pressure to increase the shelf life of a product while preserving its micronutrients. Companies like Little Tummy, a delivery service for paediatrician-developed baby food, use this technique to bring healthy-yet-convenient meals directly to parents' doorsteps. Research has shown that exposing babies to the bitter tastes of vegetables repeatedly and from early on, will get them to develop a liking for these tastes. They will go on to make healthier food choices later on in life. Incumbent baby food companies use extreme heat to ensure food safety and increase shelf life, which alters the flavour of the ingredients, destroys micronutrients and releases higher amounts of fruit sugar.

Overall, close collaboration between official stakeholders, commercial food providers and technology companies will help make children healthier, happier and stronger in the future.



Elite Performance Nutrition

by James Collins, Founder of Intra Performance Group

"Every detail which may yeild a performance advantage is carefully analysed and technology plays a crucial role"

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Performance Nutrition, as it's known within elite sport, has been an integral component of high-performance sport for over a decade – with its role now increasingly utilised by other performance-industries such as entertainment and C-suite business executives. Elite sport is often one of the earliest to either innovate or be an early adopter in the race for a competitive advantage. Performance nutrition was once a secret weapon for a sports team or individual, now at minimum it is hygiene. If you don't stay on top of the potential gains from new understanding in nutrition, you can get left behind by your rivals.

Both research and practice in the discipline of performance nutrition are rapidly evolving, spurred by advances in technology. A recent joint position statement from the American College of Sports Medicine (ACSM) outlines that "the appropriate type, amount, and timing of intake of food, fluids, and supplements to promote optimal health and performance across different scenarios of training and competitive sport."

Within the world of high performance sport, the competition schedule is gruelling: Whether you're a rider competing over twenty one stages in the Tour de France, an NBA player with four games in a week combined with cross-country travel, or an international footballer playing over 60 matches a season.

The particular nutrition themes support performance include; fuelling to sustain energy levels competition, accelerated recovery between training and competition, maintaining an optimal physique (body fat and muscle mass) and robust immune health. Indeed such is the need for sport-specific guidelines, UEFA commissioned an Expert Group Statement on Nutrition, involving 32 of the world leading experts to be published this summer.

High performance environment

There are few elite teams left from around the world that don't have a nutritionist working closely with athletes as part of medical and performance support team, including doctors, physios, strength and conditioning coaches and psychologists - covering all aspects of athletes' health and performance.

Every detail which may yield a performance advantage is carefully analysed and technology plays a crucial role. For example, within elite football the following monitoring is regularly utilised:

- Training load (e.g. sprints, accelerations, decelerations) using GPS
- Body composition (body fat and muscle mass) using dual x-ray absorptiometry (DXA) scanning
- Muscle fatigue and recovery (using force plates) combined with subjective wellbeing measures
- Hydration status and the effect on both physical and cognitive performance
- Micronutrient status (e.g. iron, vitamin D, magnesium) from blood markers
- Dietary intake using 'Snap-N-Send' from a mobile app

The nutritionist's job is to work closely with each athlete and interpret monitoring data to develop strategies for the different scenarios that athletes face during their training and competition week (the 'microcycle'). They also 'coach' athletes to strategically use food as fuel, to ensure they have energy to perform at their best when it matters most.

Food for fuel

The power of food is taken seriously within sport. Within each meal either positively or negatively influencing performance, athletes are educated to manage their fuelling depending on the demands of their day – as a competition day and a rest day will have very different energetic demands (e.g. a Tour de France rider can exceed a huge 12 g per kilogram body weight of carbohydrate to sustain performance on a race day, versus 2-3 g per kilogram body weight on a rest day).

An athlete's nutrition strategy is 'periodised' to meet their training and competition schedule, but personalisation is crucial to consider; individual objectives (e.g. reduced body fat), religious (e.g. Ramadan), ethical (e.g. sustainability), medical (e.g. allergies, intolerances) and also individual food preferences.

Great tasting food should not be overlooked – especially with so many meals over a season. In recent years, organisations have made a greater investment in their food service with Michelin starred chefs, both at the training centre and travelling with the team, who turn scientific recommendations into delicious meals, for increasingly culturally diverse professional teams.

Alongside the main focus of meeting energy intake and macronutrient targets, functional foods are constantly being tested and monitored by the nutrition team. One of the most prominent recent examples include dietary nitrate (rich in beetroot juice). This has been shown to reduce the oxygen cost of submaximal exercise (improving muscle efficiency) and enhancing skeletal muscle contractile function and improve sprint performance.

Lifting the lid on supplements

Dietary supplements (e.g. protein shakes, creatine, vitamins) remain a contentious topic in elite sport due to the very real risk of positive doping test, through the contamination of supplements (either

deliberately with banned substances or poor-quality assurance during production). With so much at stake, independent testing programmes (e.g. Informed Sport) are used alongside a robust decision making process with athletes, to minimise risk.

As such, a 'food first philosophy' is supported by the sports major governing body's as most recommended nutrient intakes can be achieved from well-planned meals and snacks.

The truth is very few supplements have strong supporting evidence and use is often driven by financial motives by a global nutritional supplement market projected to reach 245 billion dollars by 2023.

Emerging technology

Such is the pressure performance gains and fast-moving nature of technology innovation, there is an expectation for practitioners to be early adaptors of new technology to create a competitive advantage. Sports teams learned to follow the world's largest technology companies, which embed research and development teams within their organisation and frameworks to improve processes and enhance results.

This role of this team is validate internal practices and data collection with athletes. Also, with teams constantly offered the next 'miracle product' promised to improve performance or enhance recovery, R&D will monitor and assess the legitimacy of new technologies, combining the quality of evidence from research and expert option, to make graded recommendations for use.
Future nutrition advances being monitored (but not yet used) include the gut microbiome, genetics and metabolomics.

From stadium to C-Suite

The use of performance nutrition, however, extends further than the walls of high performance sports centres: The military, headline musicians and esports, right through to C-Suite executives, are increasingly onboarding the strategic use food to fuel their mission - to ensure they have the energy, and the physical and mental capacity, to maintain performance in the most demanding situations. Within Europe, Intra Performance Group, are one of the new pioneering companies applying the elite sports model to new arenas.

Whilst the focus on this short snapshot has been on performance nutrition, it's worth noting that within the active nutrition market, there will be many opportunities to apply the learnings from performance nutrition to these increasingly exercise-conscious consumers.

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Personalised Nutrition Overview

Paper written for London Technology Club
by Robert W. Beardall, MD, MPH, FACPM

Personalised nutrition (PN) is based on the concept that one size does not fit all. Instead, differences in biochemistry, metabolism, genetics and microbiota contribute to the dramatic inter-individual differences observed in response to nutrition, nutrient status, dietary patterns, timing of eating and environmental exposures. All of these have a major impact on epigenetics (the actual expression of an individual's genes) and – ultimately – health, wellbeing and lifespan.

PN has been described in a variety of ways, and other terms such as 'precision nutrition', 'individualised nutrition', and 'nutritional genomics' have similar, sometimes overlapping, meanings in the literature. While definitions vary somewhat, experts agree that, "the goal of PN is to advance human health and wellbeing by tailoring nutrition recommendations and interventions to individuals or groups of individuals with similar traits; it may integrate a variety of inputs including clinical assessments, biomarkers of physiological function and pathological processes, genetic information, data from biosensors such as activity trackers, and other available data derived from advanced technologies (1, 2, 4, 5, 8, 9)".

Several distinguishing characteristics describe the discipline of PN:

PN has emerged relatively recently; is rooted in scientific evidence; relies on analytical technologies, as well as the coaching of trained practitioners; is multidisciplinary, drawing on knowledge from other fields such as genomics, epigenetics, systems biology, medicine and behavioural sciences, in addition to traditional nutrition science and clinical practice; enables further tailoring of interventions to meet the needs of individuals or specific groups of people (1, 10).

In its 2016 position paper by Ferguson et al., the International Society of Nutrigenetics/Nutrigenomics (ISNN) proposed that tailoring nutrition recommendations to individuals or groups of people in this way "should be more effective at preventing chronic diseases than general recommendations about diet ... Recognition of diverse individual nutritional needs and responses to diet are changing standards of nutritional care, creating new possibilities for this field" (11).

In summary, Personalised Nutrition is a field that leverages human individuality to drive nutrition strategies that prevent, manage, and treat disease and optimise health.

This paper describes the key driver of PN (the chronic disease crisis) as well as its major elements including: PN science and data and PN guidance and therapeutics. These major elements combine to form the basis of an integrated PN Model of Care.

A GLOBAL CHRONIC DISEASE CRISES

The developed world is gripped by a crisis of chronic disease. Seven of the top ten leading causes of death in the U.S. are chronic diseases, most of which are considered preventable (12). In 2014, about 60% of American adults suffered from at least one chronic disease (in addition to 27% of children) and about a quarter of Americans had multiple chronic conditions (13–15). It is well established that poor nutrition is a primary driver of chronic disease, particularly cardiometabolic conditions and diet-related cancers. These conditions are also among the leading causes

of death in the United States and globally (16, 17). A recent systematic analysis for the Global Burden of Disease (GBD) sought to discern the disease-specific burden attributable to a variety of dietary risk factors; in 2017 approximately 11 million global deaths and 255 million disability-adjusted life years (DALYs) could be attributed to dietary risk factors (17). A study in the same year estimated that nearly half of all deaths due to cardiometabolic diseases in the U.S. can be attributed to poor diet (18). Mounting evidence continues to suggest that diets rich in vegetables, fruits, whole grains, legumes, and nuts are associated with lower risk of cardiometabolic diseases across various adult subgroups (19, 20).

PERSONALISED NURITION AND OUR HEALTHCARE SYSTEMS

Despite the evidence that it is core to a comprehensive approach to addressing complex chronic disease and promoting human health, personalised nutrition is largely absent from our healthcare culture and system.

The current model for treating chronic disease is a result of breakthroughs during the last century, primarily targeting acute conditions, wherein single-agent causes of illness were identified and single-agent pharmacologic treatments were developed. However, chronic diseases are now the major causes of death and disability in both developed and developing countries, outpacing the rates of acute diseases in many nations (21, 22). Notwithstanding, medical research, practitioner education, clinical care, public and private health policy continue to skew toward application of the acute-care model to complex, multifactorial conditions that develop over time. A disease-centred, acute care approach is ill-suited to chronic conditions that have multiple causes and impact multiple biological systems, as they typically have no single agent of action indicating a clear single intervention (23). These factors, often hidden from view, must be uncovered and approached comprehensively, from the standpoint of the individual's unique circumstances. Thus,

> *"PN seeks to elucidate and beneficially influence how diet shapes an individual's response to nutrients and, reciprocally, how genetic makeup impacts nutrient metabolism and nutrient requirements in service of optimising health and function".*

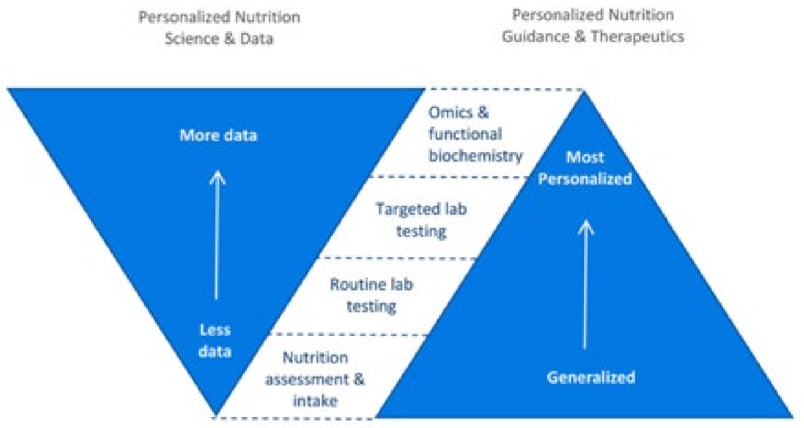

Figure 1. Interaction of PN Science and Data with PN Guidance and Therapeutics.

Major Elements of PN

PN Science and Data builds upon knowledge gleaned from traditional research methods such as observational studies and randomised controlled trials (RCTs), along with other human interventions and "citizen science" or crowd-sourced data projects (9, 24). Blumberg et al., assert that "advancing evidence-based nutrition will depend upon research approaches that include RCTs but go beyond them." (9) Emerging and advanced omics technologies also contribute to the robust PN knowledge base. Marrying methods and technologies enables better understanding of the potential impact of nutrition interventions on individuals and groups of people based on pertinent inputs and variables.

PN Guidance and Therapeutics are clinical approaches in which the individual client or patient is central to the care process and the development of meaningful recommendations, mirroring the emerging model of personalised medicine. Interventions are designed based on the fullness of available objective data including anthropomorphic, biochemical, genetic, microbial and/or omic; in addition to socio-behavioural and subjective factors such as personal and family history, cultural background and personal beliefs and preferences.

"In the PN paradigm, health and disease are not viewed as binary, but as existing along a continuum of function. Systems are not viewed in isolation, but in relationship to one another."

The PN practitioner can map areas of greatest importance across function and systems to more fully understand an individual's phenotype and nutritional needs and advise accordingly.

Richer and more robust data can inform more targeted recommendations and interventions, as illustrated in Figure 1. Results can be achieved to enhance quality of life and health outcomes with protocols based on standard nutrition intakes and assessments. When the practitioner has access to additional data for those with specific traits or health conditions, the practitioner can further tailor evidence-based strategies and interventions for individuals or subgroups with certain attributes such as insulin resistance or impaired immunity. Tools such as genomics and functional testing may be utilised for further impact on the health and behaviour of individuals now and in the future (3, 25–27). This is important as growing evidence suggests that personalising nutrition guidance and recommendations leads to more sustainable and effective behaviour change on an individual level (28, 29).

THE PN MODEL OF CARE

An individual's health status is not simply the presence or absence of a diagnosable disease, but rather the culmination of the interplay of systems and inputs – some inherited, though the majority result from environmental exposures, diet, and lifestyle. By understanding data that reflects the entirety of a patient's unique circumstances, health history, and functional imbalances, the practitioner is able to intervene at any stage: disease prevention, subclinical symptom management, disease manifestation and progression, health optimisation, and performance enhancement.

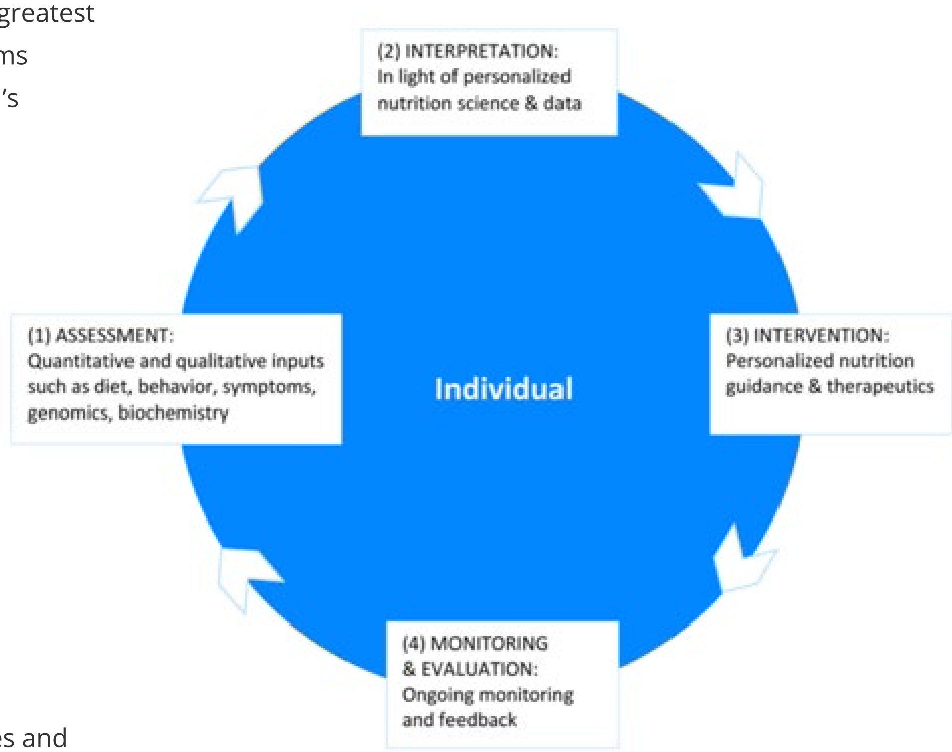

Figure 2. PN Model of Care Assessment

The proposed definition of PN points to the formulation of strategies that, when applied, prevent, manage, and treat disease and optimise health. A supportive care model creates a framework enabling PN practitioners to achieve a greater level of personalisation, and allows individuals and groups of people to benefit from strategies based on their unique

traits. This care model reflects aspects of accepted care models utilised across healthcare professions: (1) assessment, (2) interpretation, (3) intervention, and (4) monitoring and evaluation, and is adapted to meet the need for emerging personalised care incorporating new technologies that expand clinical tools in PN. As in other care models, the PN Model of Care (Figure 2) is cyclical, allowing for continual refinement of interventions to achieve the desired outcomes. More research is needed before PN will take its place as a centrepiece of our healthcare system (5). However, as PN science and data allow us to understand more about the impact of genetic, phenotypic, biochemical, and nutritional inputs on an individual's health, PN professionals will have greater ability to tailor interventions (5). A personalised model of care is the hallmark of this clinical approach.

Extensive assessment and ongoing patient input and feedback provide quantitative and qualitative information that enable the PN practitioner to gain greater understanding of the unique landscape of the individual. Readiness, motivation, behaviour, sociocultural preferences, symptoms and manifestations of dysfunction are considered alongside results of objective assessments. These include, but are not limited to, biochemical assays, advanced analyses of inflammation, oxidation and environmental contaminants, nutritional genomic reports, and microbial panels. Consideration of both subjective and objective input empowers the practitioner to create a framework for care and identify the most fruitful areas of focus and intervention.

Interpretation

The PN assessment is evaluated through the lens of the rapidly evolving body of PN scientific evidence. The PN professional considers the fullness of data gathered to create a roadmap of an individual's function or dysfunction and repletion or depletion across body systems and biochemical pathways.

Intervention

The PN practitioner uses the data and roadmap developed to design actionable interventions, education, counselling and ongoing care to address manifestations of dysfunction (i.e. symptoms) as well as the underlying root causes of imbalance. Interventions can include changes to diet; targeted nutraceuticals; lifestyle factors such as movement, sleep, and stress management; and food-related behaviours such as timing of eating, eating environment, fasting, food selection, food storage, and food preparation.

Monitoring and evaluation

Ongoing monitoring and evaluation are crucial to a robust care model, as they enable further personalisation of interventions throughout the duration of the care pro- cess. The PN practitioner regularly assesses subjective input and collects objective data in order to hone and refine therapeutic intervention strategies to build self-efficacy and behaviour change in the individual, thereby optimising quantitative and qualitative measures of an individual's health.

Integration of PN into clinical practice

In the PN model, more targeted interventions and more effective prevention and treatment may be possible as PN practitioners are equipped to assess multiple inputs and determine their distinct and collective roles in an individual's health trajectory. For instance, as genetic testing becomes more affordable, accessible, and popular, practitioners and the public have increased awareness of and access to information about gene variants that may play a role in health and disease. Genetic reports often include nutritional recommendations based on an individual's genome. Nielsen and El-Sohemy found that "DNA-based dietary advice results in greater changes in intake for some dietary components compared to population-based dietary advice," results that suggest potential for the impact of gene-based testing on tailoring recommendations to individuals (24).

To this end, the important role of the nutrition professional should be considered. Zubair et al. conducted an observational study in 2,531 participants

enrolled in a program that combined multiomic data with personalised coaching via phone. They looked at the program's impact on 55 clinical markers and the impact of genetic predisposition on changes to those markers. The results revealed "sustained improvements" in anthropometric, nutrient, inflammatory and cardiometabolic risk markers, in particular, improvements to haemoglobin A1c. Their results also demonstrated that genetic markers could be associated with longitudinal changes to these clinical markers. They concluded that: "Overall, these results suggest that a program combining multiomic data with lifestyle coaching produces clinically meaningful improvements, and that genetic predisposition impacts clinical responses to lifestyle change" (30).

Similar findings emerged from a study by Araujo Almeida et al., of 478 people who received the results of a genetic test with or without practitioner-facilitated education and interventions. The group that received practitioner-facilitated nutrition interventions had "greater improvements in diet quality … when compared with receiving a standard gene test report" (26). Studies such as these suggest that the optimal path to achieving long-term goals and outcomes may be a collaborative approach leveraging available technologies that analyse data and assist with tailoring recommendations, facilitated by trained professionals.

ADVANCES IN SCIENCE AND TECHNOLOGY ENABLING PN

The omics sciences

The "omics sciences" – nutritional genomics, epigenomics, transcriptomics, metabolomics, proteomics, microbiomics, and others – inform the elements of PN: PN research, PN education and PN practice. PN considers omics analyses that identify relevant molecules (metabolites, proteins, microbes, genes) in conjunction with analyses of body system function, nutritional, and environmental inputs, allowing for a more comprehensive understanding of an individual's health circumstances and needs (10, 31, 32). Bland, Minich, and Eck describe how these omics sciences and technologies inform personalised practice by allowing PN practitioners to evaluate, track and map complex gene expression, proteins, and metabolites, noting that, while promising, our ability to translate omics data into relevant, personalised guidance and clinical interventions is still nascent and both the data and any resulting recommendations require scrutiny (10).

Nutritional genomics

Nutritional genomics is a specific area of research exploring the interaction between genes, nutritional components, and health outcomes (33). Nutritional genomics research informs a broadening and deepening understanding of the interactions of genes, nutritional components, and health toward the application of personalised approaches, particularly within certain populations with similar traits (33). Many variants are being prioritised for future research of genotype-directed population-specific nutrition strategies.

Microbiomics

Highly individualised microbial communities residing in the gut exert influence on digestion and assimilation, thereby impacting the nutrients derived from food. These microbes also work to shape human metabolism by contributing their own exogenous enzymatic functions (34, 35). The interplay of food and nutrients with the microbiome and our genetic material influences the systems and biological processes that lead us toward health resilience or dysfunction and disease. In addition to risk for diabetes and obesity, the microbiome has been implicated in a variety of other biological processes such as modulation of host immune function and modulation of neuroinflammation impacting brain function (32, 36). Interactions between food, genomics, and microbiomics "could become the new challenge for the future in preventive medicine" (32). Thus PN will play an important role in elucidating these interactions and developing tools and strategies for the prevention, management, and treatment of a range of chronic diseases.

Approach to therapeutic diets

Although therapeutic dietary patterns are often embedded into PN plans, they must be individualised to exert the greatest positive health outcomes. The following ketogenic diet example illustrates these principles.

Ketogenic diets are designed to drive metabolism into a state of ketosis, providing ketones as a primary source of cellular fuel. The hallmarks of ketogenic diets are low-carbohydrate and high-fat; however, the macronutrient ratios needed to promote and maintain ketosis varies from person to person. Additionally, ketogenic diets can be tailored to the specific lifestyle and preferences of an individual, such as a vegan ketogenic plan. Thus, personalisation is involved in the clinical decision to select a ketogenic diet, the identification of the most appropriate ketogenic diet for that individual, and the most effective duration of the diet, among other considerations. As noted by Paoli et al., ketogenic diet therapy is the focus of ongoing research for many conditions "…such as diabetes, polycystic ovary syndrome, acne, neurological diseases, cancer and the amelioration of respiratory and cardiovascular disease risk factors. The possibility that modifying food intake can be useful for reducing or eliminating pharmaceutical methods of treatment, which are often lifelong with significant side effects, calls for serious investigation" (37).

Conclusion

PN is an emergent clinical field and discipline with tremendous potential to address chronic disease and optimise human health, performance and healthspan. PN is delineated by two major elements: PN science and data and PN guidance and therapeutics. Continued research and the development of innovative technology solutions will lead to increasingly individualised nutrition guidance, products and services. Enhanced education and training will equip a generation of practitioners who can apply personalised models of care to better support the health and wellbeing of individuals and communities.

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