New Horizons with Genomics and Artificial Intelligence and Demanding Ethical Choices

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This report considers four technology areas of relevance for the next 10-year horizon of the global food and agribusiness industry. These four technology areas experienced implementation breakthroughs in the course of 2016, and will therefore shape and influence business through the next ten year horizons.

All four technology areas have in recent years shown performance improvements by a factor of ten every two to three years. If this rate continues – and given enough demand, it probably will – each of these technologies could be at least 1000 times more potent in 2027 than today. For instance, a product related to these technologies that today costs USD 1000 per unit might cost only USD 1 in ten years. A computation that today takes one day to complete, might take only 90 seconds. A health benefit that costs USD 100,000 to achieve today, might only cost USD 100, and a particular medical procedure of today could be 1000 times more effective in ten years. The potential factor of 1000x performance improvement in only ten years creates unpredictable dynamics for the deployment of these technologies and their impact on business models.

At the same time, each of these four technology areas raises profound ethical questions, for which political and legal answers must be found. Denial of such answers might delay the further implementation of such technologies, but they are unlikely to prevent them. Delays would reduce the potential benefits of these technologies to the health and well-being of the global population, to the environmental sustainability of food and agribusiness industries, and to opportunities which food and agribusiness companies have for growth and investment.

The four technology areas are

1. Genomics / genetics: low cost and common availability of individual genomic DNA sequencing, in addition to replacement of natural DNA with synthetic DNA,
2. Software / data analytics: ubiquity of artificial intelligence computing,
3. Machinery: autonomous machinery for real-time data analysis and last-mile product delivery,
4. Social engineering: data-driven digital communication methods deliberately forming public opinion.

The fourth technology area is particularly important because of the far-reaching ethical and political dimensions of the first three technology areas. Ultimately it will be up to the choice and acceptance of the end consumers to what extent genomic sequencing, synthesized genetics, artificial intelligence, and autonomous machinery technologies will be developed and implemented. Modern computational and communication methods are available which can influence or even create these political choices in society. These methods are available to private businesses as much as public institutions. This represents an ethical question in itself, but does not change the core of the challenge: in whose interest and for whose benefit will these technologies be implemented? Who is making these choices?

> *If you learn one thing from having lived through decades of changing views, it is that all predictions are necessarily false.*
>
> Meyer Howard Abrams, literature scientist at Cornell University, 1912–2015

This report asks nine questions that are related to these four technology areas and seeks answers for the global food & agribusiness industry:

1. **Ideally, global Food & Ag industry needs to triple or quadruple its overall effectiveness in the three decades until 2050. What does this mean for technology development?** The four arguments for this question are: 1) food production needs to double in the light of on-going population growth and rising demand for higher quality food, 2) at the same time the availability of the core resources of land, water and energy may shrink, so that 3) productivity needs to triple or quadruple over the next three decades. This means 4) that technology deployment in the food and agribusiness industries will have to run at twice the speed and magnitude of the average economy…page 6

2. **Predictions in the past have been famously wrong. Which technologies can deliver the required productivity advances?** Predictions focussed on whether and when technologies will reach a confluence point, at which complementary industry supply chains, regulatory and legal frameworks and ethical approval by society are synchronized, have turned out to be advanced guessing. Instead, we should analyze the drivers of change, the motives of innovators and their institutions. When these drivers and motives reach confluence, then technologies can spread exponentially. However, exponential thought is difficult for human beings, since we think primarily in linear extrapolation. Therefore we usually get the timing wrong by anticipating a technology change too early, and once the technology has arrived, we get the pace wrong by perceiving the technology change to be too slow… page 8

3. **Genomics have improved by a factor of 10 every two to three years for the last ten years. How will this be relevant to Food & Ag?** Between the years 2007 and 2016 the cost of a human genome sequence fell from USD 10 million to USD 1000. Applying the same performance improvement rate until 2027 means that an individual genomic sequence will only cost a dime, USD 0.10, before becoming a service free of charge. Whether this development will unfold depends on whether enough consumers and companies find the information of an individual DNA genome valuable enough for them to be profiled and use this knowledge for their nutrition and health choices. This depends on how valuable their health and well-being is to them or to others…page 10

4. **Synthetic DNA is a new technology frontier. Which ethical frontiers will be allowed for synthetic DNA design in food & ag applications?** By the end of 2017, a group of researchers expects to have a copy of a yeast genome made entirely out of synthetically created DNA. The same research group wants to finish a synthetic DNA sequence also for human beings, animals and plants within ten years. Already today, genomic sciences have come to the point of being able to routinely clone mammalian animals, to prevent some genetic disorders in humans, and to create sperm and egg cells from skin. So the world is standing on the verge of being able to design a living organism according to specific wishes, including for instance resurrecting extinct species. Will ethics allow this at all? Will it allow this for plants only, for animals only – can it be prevented for humans even if it is not allowed? The technology is progressing fast, the discussion of its ethics is lagging far behind. Which zoo will showcase the first resurrected mammoth? Is species extinction a problem if we can resurrect them at any time…page 13

5. **Artificial intelligence surpassed human intelligence in 2016. What are the implications?** Human intelligence is structured in many different kinds of intelligence, including emotional intelligence, sensor and motion intelligence, communication intelligence and several more. One of those types of intelligence concern the ability to reason and strategize, and to deploy logic and mathematics. In this one capacity, AI software programs evidently overtook human intelligence in the year 2016. AI machines are able to learn by themselves in a rational and strategizing way, and do so much faster than human beings. Besides beating human beings in strategy games such as chess, Go and FreeCiv in 2016 – and poker in 2017 – AI software has already begun to replace high-level, human expert jobs such as in IT-maintenance, legal research, insurance claim processing, advertising campaign design, MRI image analysis, cancer diagnosis, pharmaceutical compound research, music composition, and the creation of motion pictures. In each of these cases, AI has already proven to be more effective, more precise, and cheaper than corresponding human experts. This is as per 2016. In 2027, these machines will be at least 1000x more performant compared to today, while human beings remain the same… page 16

6. **Artificial intelligence will reconfigure the food and agribusiness value chain. Who in the food system will benefit most?** Replacing human expert jobs with AI software machines is ultimately a simple cost-saving measure. It will happen in the same way that machines have taken over other work that human beings did before. The more relevant question is, how AI will change the business models in an industry. The answer depends on who takes the lead in using AI instruments to extract value from the value chain by having a knowledge and analysis advantage. The default setting is that it will be the Frightful Five companies (as they were called by the New York Times: Apple, Alphabet, Microsoft, Amazon and Facebook) who take that lead. The incumbent companies in food and agribusiness can still beat these five data giants to maintain their position, if they begin to build their own data and AI competences. The race is on…page 20

7. **Artificial intelligence accelerates the creation and distribution of knowledge. How can this cause another agricultural revolution?** Productivity of agricultural production in Africa and Asia is low. While there are multiple interlocking reasons for this, the primary core reason is lack of specifically useful local knowledge. The application of artificial intelligence tools that are accessible through smartphones might bridge this knowledge gap within the coming years, and thus trigger an agricultural revolution in these countries…page 24

8. **Our personal environment is becoming digitally integrated. Will the use case for an intelligent fridge finally arrive?** The arrival of the intelligent household computer which can support the daily chore of providing healthy foods for the family within the limits of a budget and taste preferences – and which can even help by self-ordering food in order to spare the trip to a super market – was predicted already decades before the internet arrived. So far, consumers have shown no appreciation for such a device. Nonetheless, the aforementioned technologies of artificial intelligence and genomic sequencing may improve the value proposition of such a device in terms of ease of use, cost and quality by several magnitudes. What we can expect is a growing and widespread acceptance for integrated systems supporting the continuous improvement of people's health status. Those personal and digital assistants will raise the need of connected household items. This may finally tip the scale within the next ten years towards widespread adoption. If it happens, then we expect adoption rates similar to the spread of the smartphone…page 26

9. **Our personal belief is becoming a commercial good. How will we create value with these technologies?** Many of the above questions entail difficult ethical choices in society. These ethical choices will become manifest in political, legal and regulatory decisions. Big data and artificial intelligence analysis have also made far-reaching advances in understanding how societies function and reach public decisions. These learnings are increasingly captured in mathematical models with considerable accuracy. This raises the question of whether the ethical decisions that are required for the implementation of the above mentioned technologies can be created as an investment – and who might buy them or invest them, and for what purpose. In an environment where the performance of some particular technologies can improve by a factor of 1000x in just ten years, both the speed and the extent of technological development calls for urgent action. Three fields of action can be recommended:

   a) Begin to integrate applications of artificial intelligence inside your company. There is a learning curve in managing and understanding this technology. There is also a learning curve in your future AI work force. The sooner your new AI colleagues (ie software machines) learn about your company and your business, the better decisions these AI colleagues will make, and the more they will contribute to the competitiveness of your business. If your business is a top-notch hospital or a top-ranked law firm, then your competitiveness already depends in the year 2017 on having those AI colleagues integrated firmly in your work force. Within a short period, this will become true for almost every company, especially in food and agribusiness industries.

   b) Consider among all your stakeholders in the company the wide-ranging ethical implications of the genomic, genetic, artificial intelligence and autonomous machinery technologies and develop a well-reasoned ethical stance toward them. The ethical dimensions of these technologies are likely to be as decisive as the technical dimensions regarding the implementation and development options. At some point, your company will need to justify itself towards your stakeholders for any extent of either using or not using these technologies. These stakeholders comprise your employees, your suppliers, your direct customers, your end consumers, the communities in which your business operates, and your shareholders. It will be helpful to prepare your company's ethical position on these technologies before a severe conflict arrives. We conducted a survey among the 34 senior Food&Ag decision-makers, and learned that they believe that ethical legitimacy will determine 30% of the value creation, up from 15% ten years ago, and 24% today.

   c) Invest in the change capacity of your company. It is not necessary to be able to outrun the lion that is chasing after you. You only need to be faster than the competitor next to you…page 29

Gustavo Grobocopatel, President of Grupo Los Grobo:
Agriculture and food business will face several disruptions. For instance, in genomics the CRISPR technology seems to have consumer acceptance and offers many possibilities for rapid change. In crop protection we see many new developments with precision agriculture being the new normal. Big Data and artificial intelligence introduce new players. I spend much of my time travelling to Silicon Valley and other centers of high technology to understand new products and methods we should apply and when. The speed of change is amazing.

www.ceibs.ch/2027
www.foodandagribusiness.org/2027

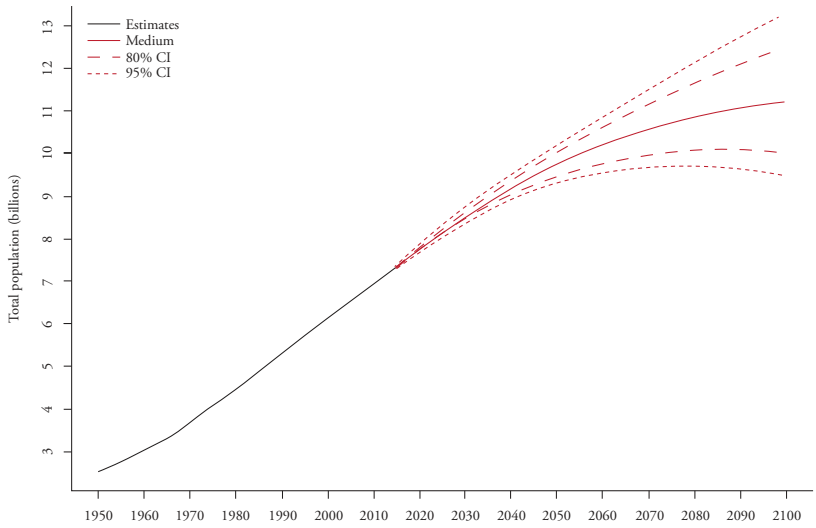
1.

Ideally, global Food&Ag industry needs to triple or quadruple its overall effectiveness in the three decades until 2050. What does this mean for technology development?

Viable predictions are forecasts based on the analysis of motives driving innovation and an open acknowledgement of foreseeable long-term developments. If such developments are supported by a strong momentum of history, then such predictions can be reliable over a long period of time. For instance, it is reasonable to assume that various trends of global birth and death rates will remain stable. Therefore, for the year 2050, the United Nations predicts that there will be around 9.7 billion people on this Earth, +/- 500 million at a 95% confidence interval.[1]

It is also reasonable to assume that the long-term trend of global productivity growth will continue at 1.8% per year until 2050, which would be the same rate as in all the decades since World War Two. The multiplication of population growth and productivity growth results in global GDP at 2016 constant purchasing power, increasing from today's USD 120 trillion to about USD 290 trillion in the year 2050. A pessimistic scenario of less productivity growth will still yield USD 250 trillion by 2050, more than double that of today.[2]

Exhibit 1 Population of the world: estimates, 1950–2015, medium-variant projection and 80 and 95 per cent confidence intervals, 2015–2100



[1] www.un.org/en/development/desa/news/population/2015-report.html

[2] Price Waterhouse Coopers PWC World in 2050 in February 2017, or the McKinsey Global Institute Report from January 2015 on Can Long Term Growth Be Saved?

A further reasonable trend to assume is that given this additional economic wealth in the world, the global community will demand more food, and better food. Better food means food with higher protein content such as meats and vegetables, and more complex food with more variety of preparation and nutritional benefits. Given past meta trends between food consumption and wealth, it is therefore safe to predict that by 2050, the world needs to produce at least twice as much food (quantity and quality combined) compared to today in 2017. For instance the French oil seed producer Avril roup expects an 80% rise in the demand for global protein based on oil crops between 2010 and 2030 only.[3]

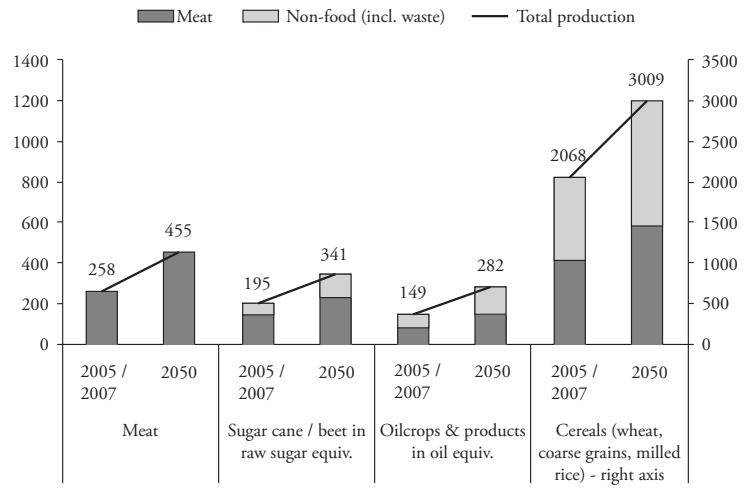
A third prediction needs to be made about resources. Will there be more or less land available in 2050? More or less water? More or less hydrocarbon-based energy? One might assume that for reasons of environmental degradation, environmental protection and requirements of accommodating the demands of urban populations, the amount of resources available for agriculture and food production will be one third less than today, but this is a much less certain prediction than the first two. The overall implication of twice the demand for food and only two thirds of today's resource availabilitywould be, that between 2017 and 2050, the food and agribusiness industry will have to triple its effectiveness. Some prominent managers of the food and agribusiness industry even propose a quadrupling.

The number of tripling or quadrupling effectiveness until 2050 can be converted into an annually necessary productivity gain of 3.4% or 4.3% respectively across the entire food value chain from grass to glass and from farm to fork. Such productivity gains are broadly twice the average productivity growth for the total global economy (the 1.8% mentioned above).

Berry Marttin, Member of the Executive Board of Dutch Rabobank:
The challenge for the world for the decades ahead is to produce twice as much food with only half the resources, which is the factor '4'.
This factor 4 is the basis for Rabobank's Banking4Food program.[4]

Productivity gains are achieved in several ways, including improved organization in companies and countries, and making better use of available but not yet deployed technologies[5]. For instance the yieldgap-atlas developed by Wageningen University shows the potential of exploiting existing technologies[5]. Nonetheless, historical experience documents that innovation and new technologies are equally indispensable to sustained productivity growth.

Exhibit 2 World production and use of major agricultural products (million tonnes)



Which allows for a fourth prediction: the global food chain industry, in all its sectors and in all its geographies combined, will need to employ at least twice as many new inventions, twice the pace of innovation, and twice the rate of technological intensificatio compared to the average global economy in all other sectors. Therefore it is likely that most innovation and technologies that come into implementation in the global economy, will either originate or quickly find their way in agriculture and the food chain.

[3] Avril Group, internal strategy document
[4] www.rabobank.com/en/about-rabobank/background-stories/food-agribusiness/banking4food-touches-everyone.html
[5] www.Yieldgap.org; developed by Wageningen University and Research and University of Nebraska

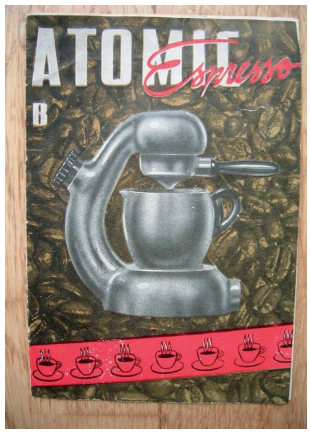
2.

Predictions in the past have been famously wrong. Which technologies can deliver the required productivity advances?

Predictions about the development and implementation of technologies are famously wrong. The 1943 quip of Thomas J. Watson, CEO of IBM, predicting a world market of five computers, is legendary. Despite this long history of failure, predictions for technology development keep being made, and keep failing. Steve Ballmer, CEO of Microsoft predicted in 2007: *There's no chance that the iPhone is going to get any significant market share.*

There are two challenges with predicting technology development. The first challenge is that the process of developing and implementing new technology requires the confluence of many different actors in society: several industries have to evolve complex supply chain relationships for the new technology, the legal and regulatory framework needs to be established, society has to grant ethical approval, and consumers need to incorporate the technology into their lives. For instance, in the 1960s Monsanto had plans for a nuclear-powered coffee machine which could keep the pot contents boiling for more than a hundred years.[6] Other companies suggested nuclear powered locomotives and aircraft, or nuclear powered heating systems for homes and offices.[7] Technically and economically all of this would have been possible. In the end only three applications became widespread: the nuclear-powered heart pacemaker, submarines with intercontinental ballistic missiles, and large scale electricity power stations. Sadly or not, Monsanto's nuclear coffee machine did not reach breakthrough in the markets, though some coffee machines in the 1950s carried the brand name *Atomic*.[8]

Exhibit 3 Atomic Espresso Coffee Machine from Italy



If and when technologies experience an inflection point at which the various societal actors become synchronized, has so far been virtually unpredictable. We only know that if such confluence is reached, then the technology will come quickly into wide-spread use. If such confluence is not reached, then the technology disappears into niches or oblivion. Quadrophonic sound was sure to enter everybody's living room in the 1970s. It never got far despite heavy advertising and clearly superior sound experience.

Therefore instead of forecasting products, we should focus on the use cases, the drivers of change, the motives of innovators and their institutions. It is a necessary task for a company's management. When these factors create a confluence point, then a product

[6] St Petersburg Times, April 10, 1969, page 12 E
[7] D. John Doyle 2015: *The Rise and Fall of the Nuclear Pacemaker*
[8] www.en.wikipedia.org/wiki/Atomic_coffee_machine

will result for which digital technology nowadays allows for exponential spread. Therefore the second challenge is exponential thinking. We, the human race, cannot think in exponential terms. Our brain can think in linear extrapolation only. We cannot train ourselves to think in exponential terms either. Therefore we usually get the speed of technology implementation wrong. In this failure, futurologists are no better in exponential thinking than managers, citizens or consumers.

It becomes even more difficult when new exponentially growing technologies interact with other exponentially growing technologies. To stay with Steve Ballmer's remark on the iPhone: not only was the spread of the smartphone itself wrongly predicted, which ruined some famous world class companies such as Nokia, but also its use for social media was wrongly predicted, which ruined Blackberry. Microsoft is still suffering from Ballmer's wrong prediction because Microsoft missed the smartphone revolution in every possible aspect: the phones come from Samsung and Apple, the operating software comes from Apple and Google (Android), the computing clouds come from Amazon (40% market share, more than twice of Microsoft, Google and IBM combined[9]), and the social interaction platforms are dominated by Facebook/Instagram. Who still remembers *MySpace*, the original social platform before Facebook?[10]

It follows that we can conduct substantial research and prepare in two meaningful ways for possible technologies:

a) We can ask today's technology leaders in existing businesses, what is it that they have in their current product pipeline which they intend to roll out in three, five or ten years' time. That is not a guarantee that these products will be successful. But we need to focus on the ambitions of those leaders to understand, how they aim to shape the future. The future we are moving towards is future we design today.

b) We can identify technologies that have reached confluence as per today, apply historical exponential growth rates on them, and then imagine how a business might look, if it makes use of such technological capabilities in three, five or ten years. This also does not guarantee that a business or the industry will make use of these capabilities, but they *can*, if they choose to do so.

We can combine Question #1 and Question #2. We can combine the impossible predictions on technology with the possible prediction on the need to grow efficiency: We know what COULD happen in terms of technology development from Question #2, and from Question #1 we know what SHOULD happen in terms of twice as fast technology development in the food and agribusiness sectors.

For *The Future of Food and Agribusiness 2027*, we are focussed on four technologies that are experiencing confluence right now, and will therefore likely see an exponential rise in their development and implementation over the next ten years. These technologies can deliver rapid productivity advances on the scale required to meet the challenge. We think in possible scenarios, of how the interplay of these four technologies COULD be changing the business of food and agribusiness companies in the near future. We will do this with the help of the answers provided by today's existing companies, and what their senior decision makers tell us about how they see the world, and how they make their investment decisions.

The four technology ares are:

1. Genomics/genetics: low cost and common availability of individual genomic DNA sequencing, in addition to replacement of natural DNA with synthetic DNA,
2. Software/data analytics: ubiquity of artificial intelligence computing,
3. Machinery: autonomous machinery for real-time data analysis and last-mile product delivery,
4. Social Engineering: data-driven digital communication methods deliberately forming public opinion.

[9] Okta, February 2017

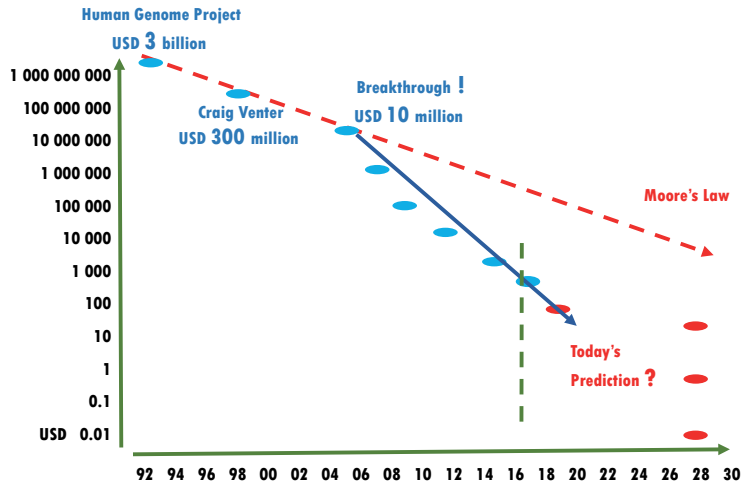
[10] MySpace was the original social media platform, predating today's Facebook, Instagram, Twitter etc. A description is for instance featured in the Financial Times article from 04 December 2009: The Rise and Fall of MySpace.

Genomics have improved by a factor of 10 every 2 to 3 years in the last 10 years. How will this be relevant to Food & Ag?

The Human Genome Project (HGP) began as an international publicly funded research project in 1990 with a budget of USD 3 billion. It had the goal to sequence most of the DNA of a human person. In 2001 the project was declared a success with approximately 22,300 human genes decoded.[11] In 1998, eight years after the start of HGP, the innovator and investor Craig Venter announced that he was spending USD 300 million to sequence a human genome at just 10% of the HGP budget, and he also declared victory in 2001, three times faster than HGP. Subsequently, until the year 2007 the cost of sequencing an almost complete human genome fell to USD 10 million. So roughly every seven to eight years, the cost of sequencing a genome has decreased by the factor of ten (which is one magnitude).

In the year 2016, the cost of an almost complete human genome sequence had dropped to a mere USD 1,000.[12] Between 2007 and 2016 the cost of sequencing one genome fell by approximately one magnitude every two to three years. This means that the pace of improvement has almost tripled. If this accelerated pace continues, the cost will be at USD 10 per sequencing in 2022, and in 2027 it will be just 10 cents. The market leader for gene sequencing equipment, Illumina, has already announced the USD 100 sequence for the year 2019.[13] The development pace is unbroken.

Exhibit 4 Development of costs for human genome sequencing

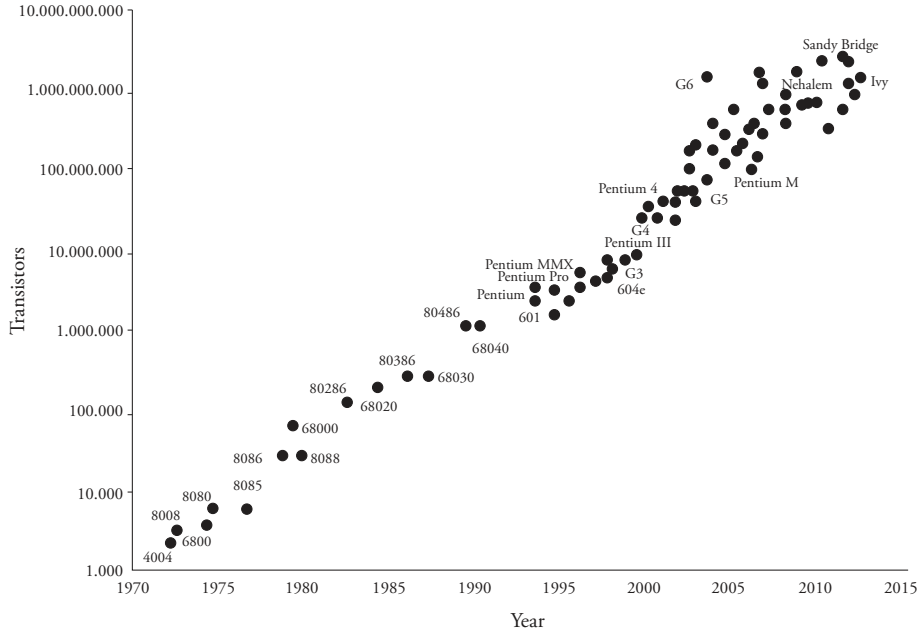


[11] Some sections of the human genome are still too complex to decode, which is why an entirely complete human genome has not yet been generated. www.pnas.org/content/113/42/11901.abstract
[12] www.genome.gov/sequencingcosts/
[13] www.techcrunch.com/2017/01/10/illumina-wants-to-sequence-your-whole-genome-for-100

There is a general lesson in this development, which is currently seen in many areas such as speech recognition, language translation, data analysis or weather forecasting. The lesson is that there is in fact a double compounding in the rate of progress. The well-known Moore's law predicts a doubling of the processing power of computer chips every two years. This is a fast rate, and means that approximately every seven years, the performance of computers increases by one magnitude (factor ten). Since the mid-2000s we have seen an additionally compounding effect: the output performance at which software makes use of a given unit of hardware can also improve. This is achieved by so-called lean software which enabled for instance the smart-phone revolution, or by the more recent advances in self-learning software, ie artificial intelligence. The combination of these two factors in hardware plus software, means that in some areas, the performance of a computer application improves by one magnitude roughly every two to three years. If this is coupled with parallel processing and rapid improvements in related fields such as chemistry, then the result can be a sustained rate of progress of factor 10 every two to three years, such as in genomic sequencing for instance. We can call this the second generation of Moore's law, or Moore 2.0. Moore 2.0 would say that the performance improvement of a technology increases by the factor 10 every two to three years in some cases.

Which reasons are there to think that the prices for a human genome sequence will NOT come down to 10 cents by the year 2027? This depends on continued improvements in the chemistry involved, the data analytics and the hardware. Historical experience shows, that if the demand is there, then more technologies will arrive. The current development pipeline for both hardware and software improvements over the next ten years provides enough room for more performance improvement. However, it is possible that there will be a legal brake on this development, or that there will not be a market for such development. Ultimately, the question whether there will be a market or not, will depend on whether enough customers find this information of their personal genomic sequence useful. One use case could be to identify one's personal health risk profile. People could customize their personal food intake towards their genetic profiles, and thereby improve their everyday health. They might also be able to reduce their bills on food and medicine, or be able to afford a personalized genetic cancer treatment, which at today's level of technology is still too costly.

Exhibit 5 Moore's law: Double # of transistors every two years



From a commercial point of view, personal genetic information is highly valuable. Health insurance companies are the natural candidates, although they operate within a tightly regulated sector of business.

DuPont or Syngenta could analyse and create genomically optimized food materials, is over. This is one major reason for them to merge among each other: their old business model is becoming history.

Jun Wang, CEO of the Beijing Genome Institute:
And in the future to me, I always think in the not far away future sequencing for everybody should be for free. So people don't really have to pay to get their genome sequence. So I think the question comes to two sides: of course the insurance company could use the genetic information against you but on the contrary you can know more than the insurance company, actually you could also try to get more benefits from the insurance company.

Financial institutions providing credit might also find this information useful. In finance, regulators will find it even more difficult than in health care to inhibit discriminatory provision of credit based on the personal genome risk profile.

It is also possible that a retailer might collect the dust of human remains each day (hair, skin, saliva) from the shop floor. During the night the retailer might analyse on the basis of the DNA genomes that were derived from the dust, which type of persons had been their customers on that day, and could adjust the product offering correspondingly for the next day. Such a scenario would be a typical example of linear thinking. Supermarkets already today have powerful tools to predict the demand for their stores for the next day. So by giving supermarkets better diagnostic tools, our linear extrapolation thinking suggests that supermarkets will improve their predictions even more.

Exponential thinking would lead to supermarkets connecting the genetic information with face recognition software and behavioural analysis tools to not only understand their consumers well enough to predict demand, but to understand them well enough to create demand. Whether this does or does not actually create demand is not a technical question, it is a question of a technology confluence arriving or not.

The genomes of animals and plants can be sequenced equally fast and cheap, as well as for instance microorganisms in the soil or in our stomachs. This will open numerous uses for genome sequence information. The era, when only a few selected companies such as Monsanto, Bayer Crop Science,

Within the next few years, genomic sequencing can be an everyday business tool for any kind of company. From 2018 onwards, every head of cattle slaughtered in Switzerland will have a DNA sample profiled and stored, so that the authenticity of Swiss beef can be assured in the retail store. The system costs CHF 7.50 per animal.[14] Soon, it might cost almost nothing.

In conclusion, it is difficult to imagine that end consumers and industrial clients will not be interested in individual genome sequencing that costs almost nothing. Therefore it seems likely that this technology development will also continue at the same pace as it did in the last ten years until it costs almost nothing. Genomic technologies used to be applied to improve the productivity of plants and animals. In the future, knowledge about the human personal genome can become part of the food value chain as well as end consumers seek personalized nutrition and health benefits. This means that by the year 2027, the analysis and daily utilization of the personal genomic sequence could be as common place as using a smartphone or a bank account is today, at costs per sequence which are fast approaching zero.

Anthony Padgett, investor in several agribusiness companies:
It is important for food and ag companies to participate in genetics or they will be left behind. Our industry has not yet fully appreciated that Silicon Valley is now their competitor for value creation in agricultural technology. The revolution that is under way in genomics is comparable to when the automobile replaced horse carts in the early 1900s...

[14] Proviande Switzerland

4.

Synthetic DNA is a new technology frontier. Which ethical frontiers will be allowed for synthetic DNA design in Food & Ag applications?

The genomic technologies do not stop at diagnostics of the personal genome in order to create better products, which was the topic of Question #3. An entirely new technology frontier has opened up, for which there is no historical precedent. The Synthetic Yeast Genome Project began in 2014 to create synthetic chromosomes of a yeast from the bottom up.[15] In March 2017 the researchers announced that five of these chromosomes have now been finished and are fully functional. The target is to create a complete synthetic yeast genome by the end of 2017. The same researchers have already begun fundraising USD 100 million to create a synthetically built human genome.[16] This project is called *GP-write,* and is expected to have created a complete synthetic human genome within ten years. The research group says that it needs to improve its technique by a factor of 3000 in order to be able to construct a synthetic human genome.

Once a synthetic human genome is constructed, the next step is to develop the technology to grow human tissue can be grown in the laboratory without needing a human starter cell. How far will it be to go from there to growing a full human organ, or to exchange natural human DNA with synthetic DNA in human embryos?

It is likely that this technology will not gain ethical approval of society and will therefore be prohibited for humans. But even so, within the next ten years it will become possible to design at least partially-synthetic genome animals with DNA optimized for particular purposes. Once the DNA can be for particular purposes. Once the DNA can be synthetically designed, the breeding process to generate new varieties can be massively accelerated. Artificial intelligence software tools will learn to distinguish between DNA which will result in a functional animal, and DNA which will lead to a non-functional animal, and then move to (re)-designing plants or animals with a combination of desired properties. The distinction will be made in computational scenarios, even before such an animal is bred in reality. If such a software tool can *compute* whether a particular DNA genome works as intended, then animal species begin to have dual lives: one in the real tangible world, and an exact copy in software code.

This creates all sorts of profound and wrenching ethical questions. For instance, can it be allowed to experiment with different synthetic DNA compositions, whether they result in a functional animal or not, as long as the experiment happens only inside a computer? What is the ethical difference between a real animal suffering from a genetic dysfunctionality in an experiment, and a virtual animal suffering from the same dysfunctionality in software code? If society does not allow this for vertebrate animals, will it be allowed for plants or worms? What does the answer to these questions say about ourselves and about our own humanity?

Will society accept animals created with an optimized synthetic DNA genome? In many countries, society did not accept genetically modified corn and exerted political pressure to disallow its use. But

[15] www.syntheticyeast.org
[16] www./www.sciencemag.org/news/2016/06/scientists-reveal-proposal-build-human-genome-scratch

this rejection did not cost much or even anything. Products with non-genetically modified corn did not cost more and had no lesser quality. Furthermore, despite widespread political anxiety, no negative health effect has ever been reported from consuming genetically modified foods.

A look at how currently available genomic technologies for animals and humans are being received, is a guide to the future. Society has already accepted without protest that nowadays animals are being cloned routinely. A cloned horse or pet will cost circa USD 85,000. In the sports of professional polo, the world's best polo player, Adolfo Cambiaso, owns the company *Crestview Genetics*, which has cloned 45 different high performance polo ponies.[17] In one prestigious match in Buenos Aires in December 2016, one side played with six identical cloned ponies. Crestview Genetics corporate motto says *Perpetuating the Finest*.[18]

> Crestview Genetics website:
> *Crestview Genetics perpetuates the finest in equine genetics through proven, state-of-the-art biotechnological reproduction processes, breathing new life into the legacy of legendary horses.*

With more demand for cloning, the cost of this technology will inevitably come down significantly as well. Will the cost levels over the next ten years reach USD 10,000 or USD 1000? This probably depends on demand. This would mean that within the next few years, a family can select on Amazon the desired traits of its future pet dog (long brown fur, medium long legs, cuddly, no allergens, etc), have the animal appropriately cloned and/or its DNA synthetically enhanced, and take delivery by courier about four months later, after a surrogate dog mother has carried out and suckled the puppy. Technically, this will most likely become possible. The question of moral and political acceptance has to remain open so far. If the pet market is the first application of this technology, then with costs coming further down per unit, farm animals such as poultry, pigs and cattle could quickly follow afterwards. Or vice versa.

Crestview Genetics has received requests asking whether humans could also be cloned, which they have declined politely. But other developments with human DNA are not very far from cloning technologies today. In September 2016 the first human baby with three parents was born in New York City. A third parent was needed to provide mitochondrial DNA, because both of the actual parents had a genetic disorder which had already given two children a debilitating and painful disease which caused one of them to die at the age of 6 years and the other at 8 months.[19]

With induced pluripotent stem cells (IPSC) yet another line of technology is going to market: In mice it has become possible to turn IPS cells from the skin into either fertile sperms or eggs. This means that theoretically, a child could be born from a single parent. Though that has not been tested yet, a clinical trial was launched in 2014 to study IPS cell treatment for age-related blindness in humans. And fertility researchers consider IPS cells to be *the next big thing* in reproductive technologies. IPSC technique would allow heterosexual couples to conceive a baby, who otherwise could not have conceived due to a genetic disorder. Another customer group would be homosexual couples who could have their own biological children without sex[20] (because the necessary contribution from the other sex can be created from one's own sex-determining stem cells).

If all the above is possible, the next step toward a biological child conceived by a single parent is only a small step to take, thus comes close to cloning. Where is the ethical line between preventing a genetic disease by providing a third mitochondrial parent, and enhancing genetic performance through a synthetic DNA replacement, once the yeast researchers succeed in creating synthetic human DNA? Where is the ethical line between prevention of genetic disease and simple enhancement of genetic performance? Is there a line? The latter would de facto be to design a human baby according to the wish list of the parents (or the future employer). So far, public reaction to these technological developments is relatively muted, indicating tacit approval. It is nonetheless likely that a strong ethical/political brake will eventually be applied on the deployment of these technologies. But will such a brake be effective if enough people want genetic enhancement

[17] The Economist, 18 February 2017, p20
[18] www.cviewfarm.com
[19] www.nytimes.com/2016/09/28/health/birth-of-3-parent-baby-a-success-for-controversial-procedure.html?_r=0
[20] The Economist, 18 February 2017, p20

anyway? History shows that neither sexual selection in Asia, nor abortion in the United States could be prevented by regulatory action.

Another thought experiment: Some group of researchers will discover a synthetic genetic modification for poultry within the next ten years, which could essentially make chicken void of any social feelings or higher-order emotions. These birds would then become pure meat producing body units with no higher-order cerebral functions, essentially a brain-less chicken. This could solve all kinds of problems during the roughly 40 days of raising a chicken to slaughter age. Today the chicken is raised in a densely packed chicken house, which creates social stress for the chicken, which leads to various negative behaviours, which lead to lowered productivity – all of that would be prevented. The gene modification would also solve the ethical problem of slaughtering an intelligent animal with a highly developed sense of social interaction, including measurable fear and sensations of emotional and physical pain when being killed.

If such a *mindless and senseless* chicken breed can be created, is that an advance for animal rights, or a retreat? Will end consumers appreciate that chicken meat can now become available without any chance of pain and social stress being inflicted on the animal, because the animal is no longer capable of having such feelings? What is the implication to our view of ourselves as the human species, when we make a judgement about making use of such technologies or not? Does our judgement change, if we consider that by not using such technologies, we might condemn hundreds of millions of human children to a diet that is poor in protein, and therefore condemn them to a stunted existence with diminished opportunities in life? Our decision whether or not to accept a technology also needs to weigh the fact that agricultural productivity has to be raised by a factor of three or four in the next three decades – which is our prediction from Question #1.

As researchers we feel safe with the following prediction: whether or not these genomic technologies become reality will not be decided by their technical feasibility. They will be decided by their ethical feasibility. Technically, they are possible within the next ten years. Ethically – we will have to decide that as society.

Exhibit 6 Adolfo Cambiaso with six clones for polo

Artificial intelligence surpassed human intelligence in 2016. What are the implications?

Chess is difficult and complex. The difficulty is related to the fact that a chess game can unfold in accordance with a total of 10^{120} possible games. Fast computers can and do calculate many of these possible games and choose the best one, but humans cannot. Therefore humans create strategies of typical moves and styles of behaviour (for instance, aggressive, surgical, grinding, barbarian, etc.) in order to play chess. The complexity is related to these strategies evolving dynamically in the course of the game and creating non-linear effects for each of the next moves. It is hard for humans to extrapolate in a non-linear way, and that is what makes chess so complex for humans.

Computers have a similar problem. They can calculate very well in a linear way, but they have difficulty responding to unpredicted, unknown or dynamic situations. In 1997, IBM's Deep Blue won against the chess world championship holder Garry Kasparov under tournament conditions. It was a sensation. Deep Blue relied on processing power for calculating 200 million possible moves each second. But it did not learn in the course of the game to improve.[21] Deep Blue was only as smart as its programmers were, and it outperformed Mr Kasparov mostly on raw computing power, aided with some pre-set execution strategies. This was not yet artificial intelligence (AI).

The real breakthrough year, or confluence, for artificial intelligence can be considered to be 2016. For instance, in summer 2015, Richard Lai was a graduate student in computer sciences at the University College of London. As his master thesis, Mr Lai created *Giraffe*, a self-learning chess software program that was able to teach itself chess within 78 hours to become equal to 98% of all human ranked players.[22] Giraffe was not able to play better chess than Deep Blue or its successors did, but it was able to learn to play chess by imitating the human ability of intuition.[23] In contrast to Deep Blue, this is true artificial human-like intelligence. Mr Lai's thesis was called *Giraffe: Using Deep Reinforcement Learning to Play Chess*. He then abandoned the project and began working for Google at the *Deep Mind* division. That division produced the software *Alpha Go*, which beat one of the world's best Go players in March 2016, and received the 9th Dan in Go from the Korean Baduk Association. It was long acknowledged that only self-learning and strategizing computer programs would be able to play Go, because its number of possible games amounts to 10^{761}. No linear software can calculate this, no matter how strong its hardware. The goal to think like a human in Go was reached in 2016.

In December 2016, AI reached a further milestone. The German Frankfurt based company *Arago* announced that its AI software was able to beat 80% of all players in *FreeCiv*. *FreeCiv* is a strategy game with 10^{15000} possible games, ten times as many turns (between the two players) as in chess, and including a randomness feature (while chess and Go are not random).[24]

[21] de.wikipedia.org/wiki/Deep_Blue
[22] qz.com/502325/an-ai-computer-learned-how-to-beat-almost-anyone-at-chess-in-72-hours
[23] www.motherboard.vice.com/en_us/article/the-chess-engine-that-died-so-alphago-could-live-giraffe-matthew-lai
[24] www.arago.co/hiro-freeciv

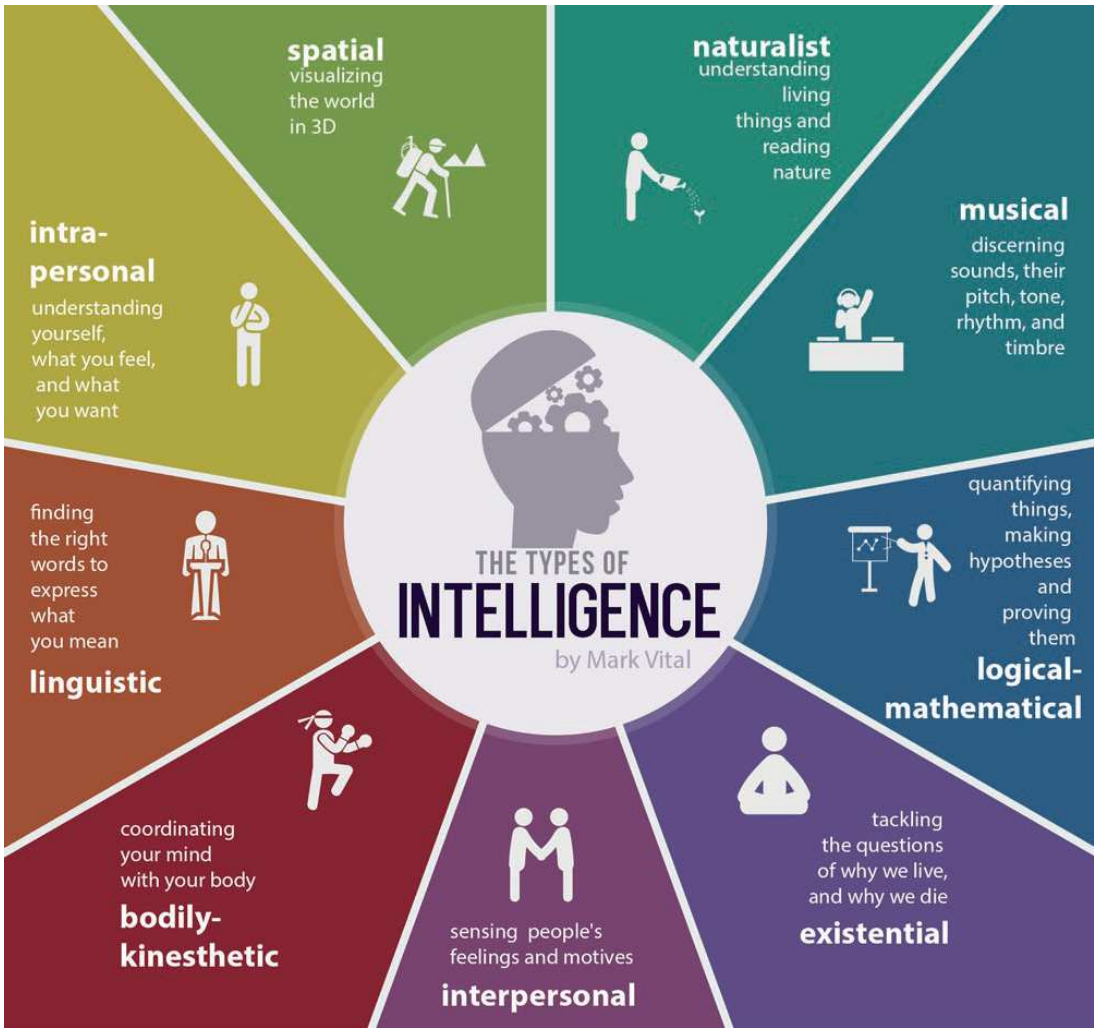
By the end of 2016, the conclusion became unavoidable that AI had become better than human beings in one type of human intelligence.

There is not one single human intelligence. Humans have reasoning capacity, emotional capacity, linguistic capacity, and so on. There is not a single agreed definition of how many types of intelligence there are, but the framework by Howard Gardner is one that is frequently accepted.

The computers which could beat humans in Go and FreeCiv are now surpassing one of these nine intelligences, which is the human logical/mathematical ability to reason, strategize and think analytically. The revolution which this technology can unleash is not that the computers can calculate faster than humans (they have done this since the 1940s), but that they can now learn to reason and strategize faster and better than humans. It takes a human Go master several decades of training and experience to reach the 9th Dan. Google's software could reach that in just a few months.

The ability to learn itself includes and to some degree even relies on the fact that the software is able to program itself. This means that one and the same software program may make very different decisions after being *alive* in different environments for some time. It also means, that software programs begin to develop context-dependent personality and maturity, just like a human being would. An AI software machine which has been exposed to a smarter and more advanced environment during its learning phase, and was able to train itself on better data, will also be smarter and more advanced in its decision making than its peer.

Exhibit 7 Nine intelligences according to Gardner



The advertising agent of the New York based company Adgorithm is an AI software machine called AlbertTM (trademarked). Since AlbertTM is one of the first AI agents on the market, he (or she or it?) will likely be smarter and better and outperform competition for a long time. AlbertTM is clearly not a human being, but is he/she/it becoming a person? Why, or why not?

Machines are still several decades away from becoming smarter than human beings in general. A human person consumes on average 2500 kcal per day, which is roughly 3000 watts per day. Of that, 750 watts are used by the brain and the neural system (ca 25%). Put differently, the human brain works with about 30 watts of energy per hour. For the equivalent amount of computing which a human brain performs during an hour, a computer would consume about 10,000,000 watts per hour. The electricity bill for this is about USD 1000 per hour (assuming 10 cents per kwh).[25] This is just one indication that computers are still around seven magnitudes less efficient than humans.

On the other hand, if we apply the performance improvement rate from genomic sequencing of about two to three years per magnitude, then this means that machines might equal the complete human intelligence in about 20 to 30 years. This is one of the indicators which futurologists use to speculate on a date between the years 2040 and 2050 for the moment of singularity – the moment at which machines surpass human intelligence on all levels. The key question here is not whether it will happen, but when it will happen. If computers improve at the rate of about one magnitude of performance every two to three years, while human beings stay the same, then inevitably the two lines will cross in the foreseeable future.

> Dr Stefan Mück, CTO Cognitive Solutions and IBM Distinguished Engineer and Executive Partner IBM Deutschland GmbH:
> *Artificial intelligence will be relevant in all those instances, in which human language plays a role. .*

Elon Musk, the founder and owner of Tesla automobiles and Space X rockets and the driving force behind the Hyperloop, started a company in March 2017, called Neuralink. This company has the target to create computer implants for human brains, so that human beings can make direct use of the computing power of such chips, rather than working through slow and cumbersome input/output devices such as eyes, ears and hands. Mr Musk has repeatedly stated that the computer chip-enhanced human brain is the only possible human defence against the inevitable rise of artificial intelligence.[26] If Mr Musk is right, how will luxury be defined in the future? As the ability to afford chip-enhancement and thus out-compete normal humans, or as the ability not to have to become chip-enhanced, because one is rich enough not to have to work?

Exhibit 8 Description Neuralink according to their website

NEURALINK

Neuralink is developing ultra high bandwidth brain-machine interfaces to connect humans and computers.

We are looking for exceptional engineers and scientists. No neuroscience experience is required: talent and drive matter far more. We expect most of our team to come from other areas and industries.

We are primarily looking for evidence of exceptional ability and a track record of building things that work.

All positions are full time and based in San Francisco.

[25] Matt Mahoney 2013: The Cost of AI
[26] www.theverge.com/2017/3/27/15077864/elon-musk-neuralink-brain-computer-interface-ai-cyborgs

As far as the horizon of this report on *The Future of Food and Agribusiness 2027* is concerned, the moment of singularity is still far away, because we are looking only at the year 2027. Even then, the pace is explosive. Global venture funding for AI companies surpassed the USD 1 billion mark for the first time in 2015.[27] The year 2016 saw funding in excess of USD 5 billion[28], and the pace in 2017 is set to break another record most likely in the double digit billions. The US Pentagon alone has earmarked USD 18 billion for the next three years to develop AI technologies for its weapon systems. Russian and Chinese military investments in AI are said to be on a similar scale.[29]

In principle and in accordance with Moore 2.0, AI technology will improve by one magnitude (factor 10) every 2 to 3 years. So one dimension is that AI can tackle ever more complex problems, such as creating public opinion, forecasting the weather over a period of three months, delivering real time economic performance data of industrial economies or predicting the price of milk in the wholesale markets for next year. These are super human tasks, and because of their complex nature could not be understood by the algorithmic computer programs of the recent past. AI may eventually be able to solve these tasks.

Another dimension is to make the strategy and reasoning power of a 9th Dan Go master available as a free-of-charge app on the smart phone. At current rates of technology improvement, this would be likely to happen within the next few years. Simple do-it-yourself AI applications are available as freeware. Google open-sourced *Tensorflow*, the AI engine driving the program Alpha Go, already in November 2015.[30] As just one example, the company *AI-one* offers self-development kits for creating AI programs.[31] When the AI program of IBM, Watson, played and won against the two best human players of Jeopardy in 2011, the computer still occupied an entire room. In 2014, IBM decided to invest USD 1 billion into the Watson business unit. Today, Watson runs in the cloud and has no physical presence anymore. It is part of IBM's *Strategic Imperatives* portfolio, which accounts for 38% of all of IBM's business, according to its financial statements. Watson is already an app, though not (yet) free-of-charge on the phone and being advertised by IBM with these words: *Enable your app to learn, reason and consider context with Watson analytics services available on the Bluemix cloud platform from IBM.*[32]

[27] www.appcessories.co.uk/artificial-intelligence
[28] www.cbinsights.com/blog/artificial-intelligence-startup-funding
[29] www.news.com.au/technology/innovation/inventions/robotics-scientist-warns-of-terrifying-future-as-world-powers-embark-on-ai-arms-race/news-story/d61a1ce5ea50d080d595c1d9d0812bbe
[30] www.wired.com/2015/11/google-open-sources-its-artificial-intelligence-engine
[31] www.ai-one.com
[32] www.ibm.com/cloud-computing/bluemix/de/watson

6.

Artificial intelligence will reconfigure the food and agribusiness value chain. Who in the food system will benefit most?

The Stanford Artificial Intelligence Laboratory employs more than 20 principal researchers and many more PhD students to develop various applications of self-learning software mostly related to the automotive sector. One of the challenges is to teach computers how to recognize finely grained differences in objects and classify them accordingly – for instance how to recognize different models of cars which are in the wild, meaning which drive around and whose pictures are captured in different light conditions, different angles and different quality of resolution. In a 2016 project, the researchers Fei Fei Li and Timnit Gebru developed a program that could analyse 50 million Google Streetview pictures to allocate a car in 0.2 seconds per image into one of 2657 different categories of cars. These 50 million pictures were taken in 200 US cities, representing around 8% of the US population. Ultimately the computers could identify 22 million distinct vehicles in the pictures.[33] The 2657 categories represent almost all different models available for sale in the US since the year 1990, from the Honda Acura model 1997 to an Aston Martin 2015.

Then the researchers let their AI software learn, by comparing the presence of cars with census and election data supplied for 35 of the 200 cities. The machine was supposed to learn by itself to predict voting preferences, educational status, income status etc of the residents in these cities on the basis of knowing which cars were driving around in these cities. After the machine learned these relationships it was then tested on the other 165 cities to what extent it could predict these sociodemographic features down to precinct level (which is a unit of about 1000 inhabitants). The researchers found that their program could for instance predict: median household income with 67% accuracy, percentage of Asian population with 76%, or percentage of people with a graduate degree 49%. Simply counting the numbers of sedans versus pickup trucks was an indicator whether the city was voting Democratic (88% chance if there were more sedans), or Republican (82% if there were more pickup trucks).

There are many datasets which provide more finely grained and more accurate information about the residents of precincts or streets in the United States. The key significance in the above research is that the insights could be gained by the AI software within only two weeks of categorizing visual images of just cars. This is an inherently cheaper and faster method than other data gathering methods. In this particular case, the rival is the US government, which spends each year USD 250 million to update its census information by walking from door to door. The information is then collated, evaluated, approved and finally released. Usually it takes two years for the data to become available, and for less populated regions which are sampled less frequently, it might take up to five years. Ms Gebru on the other hand could achieve similar, though somewhat less precise results with letting 200 cores of 2.1 Ghz CPU and 4 Tesla K40 GPU computer resources crunch the numbers in two weeks only. If the competitor were

[33] Timnit Gebru, Feifei Li, 2017: *Using Deep Learning and Google Street View to Estimate the Demographic Makeup of the US*

a private company spending USD 250 million each year to produce these data, it would very soon be out of business in the face of the much higher competitiveness of Ms Gebru's machine.

So far, Ms Gebru's machine delivers crude results. But it can improve by a factor of ten every two to three years, while the door-to-door method does not. If the AI machine becomes more powerful, is fed with more data and is programmed to investigate more objects than just cars, for instance the type of clothing which people wear, the type of houses or the state of repair of streets and other indicators, then the program could identify ever more finely grained information about those residents at a fraction of the cost of what it would cost to assemble these data from the ground up. In three years' time and applying Moore 2.0, Ms Gebru's computer can either process 500 million pictures in two weeks, or it can process 50 million pictures in 34 hours. Or given enough financial resources she could also deploy not just 200 CPUs, but 2000 CPUs, 20,000 CPUs or even 200,000 CPUs for any task that she cares to undertake. She will not need to buy these CPUs herself, as she can rent them from among the estimated 3 to 5 million servers which Amazon provided in its cloud as per 2015, a number which is growing each year by about 80%.[34]

Google Streetview is not the only source of imagery data on Earth. The company *Planet* has a fleet of 149 satellites in orbit, each of them 10 cm x 10 cm x 30 cm in size. This fleet takes a picture of the entire world once per day, at a resolution of up to one meter. Customers can in this way track daily changes of any geospatial circumstance, such as containers in a port, status of vegetation in the fields, number of cows on the meadows in Netherlands, hectares of rapeseed planted in Germany, or quality and quantity of soy beans harvested in Argentina – with daily changes. The time delay between the picture being taken and supplied to the customer is only a few hours.[35] Planet already has hundreds of global customers using this data for their analyses.

Another application where AI is changing the rules of the game is weather forecasting. For instance has invested resources into creating weather forecasts with AI rather than the traditional rule-based scenario algorithms. Yandex, which is the Russian version of Google with 60% market share for search engines in Russian, has announced its product Meteum which forecasts weather based on AI programs. As of now, the technology still lags behind the traditional methods.But it can improve by a factor of ten every two to three years, which may eventually make forecasts possible that are thought to be impossible today.

There are numerous incidental applications of AI, ranging from the trailer for a movie created by AI (the film Morgan in 2016), a website where AI creates music on demand (Amper), the company Adgorithm in New York xwhich claims that the Harley Davidson NY branch was able to expand its sales by 40% using its AI supported marketing methods,[36] law firms which are implementing AI-driven legal research at a fast pace,[37] and insurance companies which are replacing their claims departments with AI-computers.[38] In agriculture, just about every piece of machinery is acquiring artificial intelligence self-learning capacity: from the self-learning milking machine to the self-learning pesticide spraying drone and self-learning irrigation system.[39] In the field of genomic sciences, AI applications are accelerating the identification of protein folding structures at multiple magnitudes, thus beginning to unravel the mystery of the proteome.[40] In retailing, the German company Otto uses an AI machine originally developed for particle physics experimentation at the CERN laboratory in Geneva, to predict with 90% certainty what will be sold within 30 days and on that basis to automatically order 200,000 different items per month from its suppliers.[41]

[34] www.datacenterfrontier.com/inside-amazon-cloud-computing-infrastructure
[35] www.planet.com
[36] adgorithms.com/about
[37] www.insidecounsel.com/2017/02/17/the-actual-cost-of-in-house-artificial-intelligenc?ref=most-popular&slreturn=1490986526
[38] www.lemonade.com
[39] Victor John Tan by ai.business, 2016: *20 use cases in agricultur*e
[40] The Economist, 11 February 2017, p 63
[41] The Economist, 15 April 2017, p 56

Jean-Marc Dublanc, CEO of Adisseo, a global animal feed ingredients specialist: *Our industry is a bit late, because Artificial Intelligence with Big Data collection and analysis are coming towards us very fast. We must employ this both for our internal processes, and for improving our products. We must and will have this technology available to us, either through internal development, or by purchasing it..*

All of the above increases productivity in meaningful ways, but these are linear effects. The more difficult question is, what might be exponential effects of change? The core question therefore is not whether AI will change value chains of an industry, also the food and agribusiness sectors, but how. And who will profit from these changes? For an answer, the value chain could be divided into four different categories of companies who create and harvest value:

a) producers and processors of various kinds of food products and services, from potato growing to restaurants,
b) predictors, who thanks to superior insight derived from data access and data analysis know how much of which product will be needed when and where,
c) creators of demand, who, thanks to marketing methods, ownership of brands, contractually guaranteed control over idols (sports stars for instance) and advertising power to the end consumer, conjure demand for products,
d) data providers and data analysers, who feed data or analysis results to each of the above, producers, predictors and demand creators.

The first three categories have existed since a long time. They are called farmers, food processors and food service for the first category, wholesale traders and financial markets for the second category, and FMCGs (fast moving consumer goods) and brand owners for the third category. Each of them makes their respective investments in land or machinery or knowledge which will pay an adequate investment return. The fourth category is new. In the past, companies in each of the first three categories had their own data and leveraged them as much as they could. The farmers knew their plots of land, the processors had their industrial knowhow, the traders had their intuition, experience and knowledge of trade flows, and the FMCG had their understanding of customer segmentation and response rates to branding efforts. Looking into the future, each of the three classical kinds of companies will now depend on having access to the data providers and data analysers for their business survival. The question is, how expensive will that access be?

So far, these data specialists form a nascent sector with a large spectrum ranging from fledgling start-ups to small and medium sized enterprises, internal R&D/IT departments in agri-food companies, and established software firms developing solutions. Most of it is in the prototype phase. One force that could change this situation, are the *Frightful Five,* as they are called by the New York Times.[42] The Frightful Five have accumulated mountains of data in the past years, whose extent will be nearly impossible to replicate by any other company ever. The Three Trillion Dollar question to the future of the world economy is – how valuable will these data be? The answer depends on how much value these companies will be able to extract from all other industries, including the food and agribusiness industries.

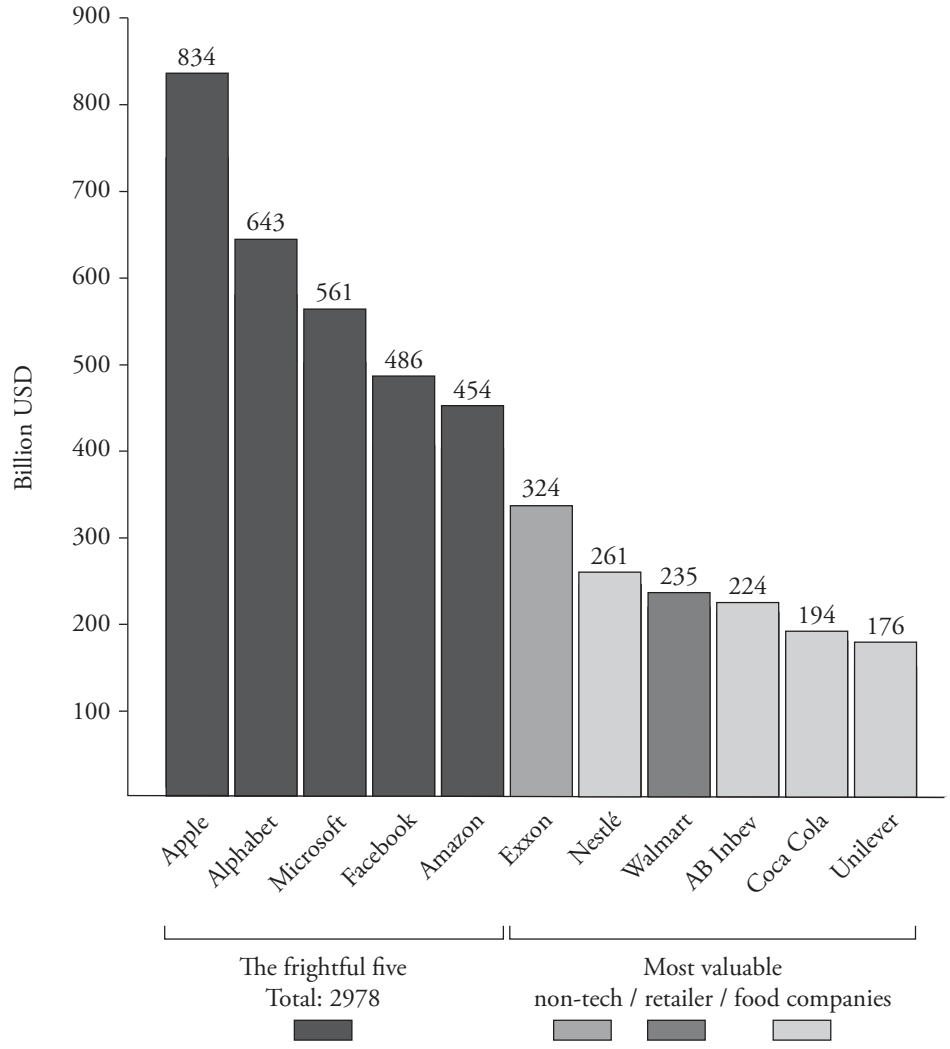
Financial markets currently value these mountains of data at around three trillion dollars. The Frightful Five are Apple, Alphabet (Google), Microsoft, Facebook and Amazon – respectively the five most valuable companies in the world. Together they have a stock market valuation of 3 trillion dollars (Aug 2017), which is more than the GDP of the UK (itself the fifth largest economy in the world).

The total food and agribusiness portion of the world economy is about 25%, so around USD 30 trillion per year (2016 USD according to PWC). Assuming a corporate profit rate of 10% of GDP, which is a long-running average, the total net profits of the global food and agribusiness industry amounts to about USD 3 trillion per year. The open question that everybody is seeking an answer for, is: How much of this profit will need to be shared with the Frightful Five in the future, in order to justify their stock market valuation? And how will the availability and access to the data of the Frightful Five change the value chain? Are FMCG the winners or the losers? Are retailers the winners or the losers? Are the owners of tangible values such as

[42] www.nytimes.com/2016/01/21/technology/techs-frightful-5-will-dominate-digital-life-for-foreseeable-future.html?_r=0

land or machinery the winners or the losers? None of the above – and at the same time potentially all of them. The data are useless, unless they are made senseful by data specialists. So far, artificial intelligence is only one of many ways to produce such sense-making, in the future it will become ever more prominent. Therefore – so far – any player who begins to build their own data analytics and AI competence now, can have a head start over all other participants in this race, regardless of their position in the agribusiness value chain.

Exhibit 9 Selected stock market valuations Aug



7.

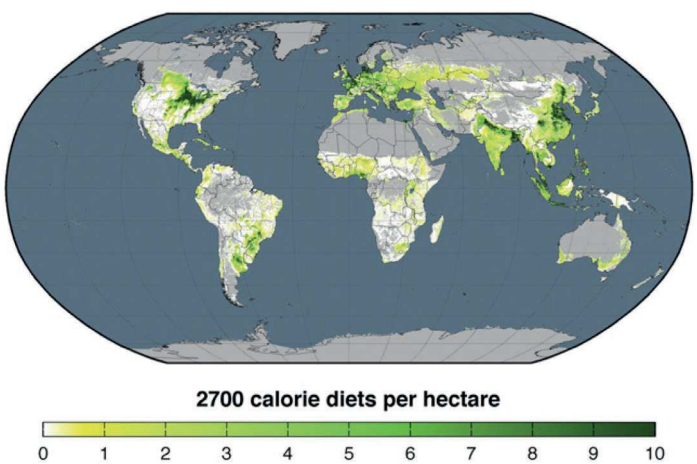
Artificial intelligence accelerates the creation and distribution of knowledge. How can this cause another agricultural revolution?

Much of the world's agricultural production is in a poor state of affairs. Productivity in growing food is very different around the world. Across all cereals, the range is from around two tonnes per hectare in the poorest regions to about nine tonnes per hectare in North America. This metric can also be converted into the number of people fed per year per hectare to show the uneven spread of agricultural productivity in the world.

The problem is well known and many organisations are attempting their best to bridge the gap. If this gap were to be narrowed, this would mark a major step towards solving the overall productivity challenge of the global agribusiness industry. The reasons behind the productivity gap are complex and interlocked. They span from low rates of mechanization, small plot sizes, poor quality seed material, poor quality of fertilization schemes, sparse availability of crop protection pesticides and herbicides, poor soils, difficult climate conditions, limited access to markets, high cost of access to financial tools and credit, as well as manifold sociocultural barriers.

The one common theme to induce improvement in most of these topics is on demand tailored and context-dependent advisory services focused on de-risking agriculture production from the perspective of the primary producere. It does not help a Subsaharan farmer to know that in general he should be using more fertilizer, if he does not know how much more, at what time to use it or in which combination with which seed, all of which depends on his very specific circumstances.

Exhibit 10 Number of people fed per hectare by total calories produced



The usage also needs to be synchronized with the current rainfall pattern, cost and availability of types of fertilizer, understanding of crop protection chemicals and access to finance. The circumstances can be very different from one village to the next, from one crop to the next, and from one season to the next season. Moreover these environments are often data-poor: it is unknown where farmer fields exactly are, who owns them, what was on them, all of which combined with an extremely high spatial variability in soil conditions.

How to effectively bridge the gap of generic knowledge to tailored, context specific advice has been the subject of numerous well-intended schemes aiming to raise the low productivity of farming in many poor parts of the world, most of them in Africa and South Asia, primarily by employing extension workers. However, extension workers are too few and too scarce on the ground with the farmers to be able to induce widespread change. Also, the extension workers themselves are often not equipped with sufficient knowledge.

Most remote farming communities in Subsaharan Africa and South Asia have gone through one technological revolution already: the spread of the mobile phone, and quite often already a smartphone. By 2019, in India 40% of people using mobile phones are expected to have switched to smartphones. In Africa the rate is expected to be 57% by 2020.[43] The spread of smartphones will enable data analytics and AI instruments to provide precise instructions to local farmers on the use of seeds, fertilizers, crop protection measures and soil treatment measures. These AI instruments can for instance draw on satellite imaging data for understanding highly specific local soil and growing conditions, it can connect with weather history and forecasts, and it can connect with local and global market conditions to create specific knowledge for a particular plot and a particular crop. It can also translate this information into the local language of the farmer, and should he or she not be literate, provide a speaking and listening interface. Such programs are currently already being researched and developed.[44]

As per today, AI is not powerful enough to provide this scenario reliably enough, but at a pace of improving itself with a factor of ten every two to three years, AI will be able to do so within the next few years. The spread of smartphones will then go hand in hand with the spread of specific and targeted advice to the individual farmer on his small plot. Such AI instruments can also be coupled with the provision of financial instruments, so that access to financial products in remote rural areas will also be coordinated via the smartphone.

Often the poor productivity is blamed on the small size of the farmed plots in Subsaharan Africa and South Asia, which prevents increased rates of mechanization and therefore condemning the land holders to marginalized subsistence farming. The economics of this argument are doubtful in two ways. First, there are many examples around the world which prove that small sized plots can still be highly productive. Rice farming in Japan has a very high land productivity, even though the plots are rather small. Second, there are strong benefits to a society having a social security net in the form of widespread and dispersed land ownership, rather than having to rely on unstable governmental institutions of weak states. The issue is also theoretical: the lands in Africa and India are densely populated and the people will likely stay. The provision of AI technology might solve the challenge of raising farm productivity without large-scale land expropriation, which is politically and socially neither desirable nor feasible.

A second unusual feature of rural life in Subsaharan Africa and South Asia is the relative shortage of crafts. Rather than having a local tool maker, or a local carpenter, or a local food processor, these rural economies are characterized by self-sustaining households. They export raw materials and import most tools and products. The problem here again is knowledge, and the dispersed availability of vocational training to develop such local crafts. In this instance as well, the knowledge and development has to be local and specific, and otherwise it will not match the local needs and circumstances. AI-driven knowledge transfer and training schemes could help fill this gap as well, because the AI-machine can learn to become specific and decentralized enough in a way that centralized training schemes can never achieve.

On balance, the transfer of specific, localized knowledge which will become possible with AI instruments should be able to propel productivity growth in farming in Africa and South Asia. It will not solve all problems, but it can solve many problems. This will release hundreds of millions of people from severe poverty, and it will contribute a substantial portion to the overall productivity advance that is required on a global scale.

[43] www.mobileworldlive.com/featured-content/home-banner/africa-hits-557m-unique-mobile-subs-smartphones-to-dominate-by-2020

[44] For instance: A 30 million Euro Internet of Food and Farming project coordinated by Wageningen UR and funded by the European Commission, www.iof2020.eu; or through the Geodata for Agriculture and Water program of the Netherlands Ministry of Foreign Affairs, connected Remote Sensing data to Agricultural applications, g4aw.spaceoffice.nl

8.

Our personal environment is becoming digitally integrated. Will the use case for an intelligent fridge finally arrive?

The intelligent fridge at home has been one of the most prominent recurring technologies to be predicted over the past decades: a system which self-orders food from the supermarket, to be delivered by mail or a dedicated logistics system. This prediction is as old as the computer itself, predating even the internet, and it has so far failed to materialize even as a niche product.

LG followed in 2003 with its Digital Multimedia Side-By-Side Fridge Freezer with LCD Display. Each year since sees ever fancier intelligent fridge combinations which consistently fail to excite the consumer.[46]

The Honeywell h316 from the year 1969 weighed 46 kilograms and cost USD 10,000 at that time.[47] It was apparently sold only a few times.

> Ad copy text for a widely advertised kitchen computer in the United States:
> *If she can only cook as well as Honeywell can compute. Her soufflés are supreme, her meal planning a challenge? She's what the Honeywell people had in mind when they devised our Kitchen Computer. She'll learn to program it with a cross-reference to her favorite recipes by N-M's own Helen Corbitt. Then by simply pushing a few buttons obtain a complete menu organized around the entrée. And if she pales at reckoning her lunch tabs, she can program it to balance the family checkbook.*

> Ad copy text for V-Sync Internet Refrigerator introduced in 1998:[45]
> *With a speedy Pentium II microprocessor and huge hard drive, it packs more computing power than most home PCs, and has separate compartments for fruit and vegetables.*

It is easy to understand why the intelligent internet fridge failed to arrive in the kitchen in 1969, just as much as it did not arrive in 2017. We have to focus on use cases and technological drivers instead of following the rise – and often the decline – of products and marketing campaigns.

Nonetheless, combining the previously mentioned technology of the ten US cent genome sequence, any smartphone app with a learning ability equal to the reasoning skills of a 9th Dan Go master, and all sorts of self-learning machinery that populate our lives as intelligent bots, could finally pave the way for intelligent household items. A fairly promising candidate will not be the fridge, but the intelligent internet-connected toilet. After all, only the toilet offers direct access to real time genomic information.

The intelligent toilet at home analyses on a regular basis the genomic composition of the intestinal bacterial biosphere of each of the family members. The toilet will then order from the local supermarket and bio-organic local farm, the requisite foods that will optimize that intestinal biosphere towards

[45] Mike Kuniavsky: Smart Things: Ubiquitous Computing User Experience Design
[46] www.orangecone.com/archives/2008/01/the_fridge_comp.html
[47] gedankenstrich.org/2013/12/heute-ist-die-zukunft-von-gestern-xv-der-honeywell-kitchen-computer-1969

Exhibit 11 The Honeywell Kitchen Machine anno 1969

reducing headache, minimizing allergy and increasing mental concentration power, besides preventing diabetes and reducing the likelihood of cancer.

The foods can be delivered easily by the autonomous self-driving container bots that are currently being extensively tested in various cities around the world. For instance Piaggio from Italy and Starship from Estonia have had prototypes on the streets since 2016. They expect the cost of a delivery to be around 1 USD /EUR per trip, and can deliver up to 18 kilograms of cargo.

The intelligent toilet might then suggest five different cooking recipes for each evening that optimize the criteria of taste preferences, budget and cooking skills with those aforementioned health targets. The toilet has learned about these criteria from the analysis of its own deposits, and can of course include additional information from different audio-visual sources in the living sphere of the respective family.

The intelligent toilet will also coordinate with the automatically recorded daily activity profile (formerly known as calendar) of each family member to adjust the amounts of food that are ordered and prepared. Or cooking could be discarded altogether: the intelligent toilet may directly instruct the kitchen mixer to prepare the appropriately blended shakes with the optimal composition of nutrients for each member of the household, and in the favorite taste preferences.

The toilet will also know via its internet connection that it will rain next Saturday. From past experience it even knows the names of the favourite movie stars of each family member. The toilet has therefore already reduced the ordering of perishable food for the weekend, and pre-booked tickets for the cinema. Should the family decide not to go to the cinema, the toilet will sell the tickets on the open spot market. Since it is the movie opening weekend, the toilet is certain that it will sell the tickets. The toilet will also inform the electronic underwear closet to impregnate the underwear with bioactive pheromonic ingredients suitable for supporting the mood of a family during a weekend outing. Finally, the toilet recognized this morning a slightly raised immune system response of the family's nine-year-old, and knowing from the other toilets in the neighbourhood that a flu is again making the rounds, it adjusts the food intake and sends a message to the smartphone device of that 9-year-old to make sure to wear a sweater today.

To be clear: Every advanced item of our daily life has the capacity to gather and analyse all of this information. The digital ecosystem is becoming the dominant player, with connected devices of all sorts following. It's not the device which matters, it is the use case. The toilet offers direct access to genetic information, a key to optimizing nutrition, health status and increased longevity. This makes it the primary candidate to be the center piece of all connected devices fulfilling the use case of digitalized household support.

Exhibit 12 Modern delivery bots

Starship Technologies - Delivery Robot

Starship Technologies was launched in 2014 by Skype co-founders Ahti Heinla and Janus Friis. Its business headquarters are in London and its engineering in Estonia. Heinla and Friis realised there was a huge opportunity to disrupt the delivery industry – an industry that hadn't been disrupted and revolutionized by technology yet. They set to work creating a last-mile robotic delivery solution, which is when Starship Technologies was born. Starship has built the first commercially available autonomous delivery robots. The robots are designed to manage local delivery of packages, groceries and food. The robots will deliver up to 10 kg weight (three shopping bags) within 30 minutes, to homes within a 3-mile radius – all for as little as £1. The robots can be requested by the consumer completely 'on-demand' through a mobile phone and delivered at any time of the day.

Piaggio Fast Forward - Gita

Piaggio has remained a world leader in light mobility for 130 years by combining advanced engineering with design that empowers and delights, the Vespa being its most famous product. Piaggio Fast Forward was founded in 2015 by the Piaggio Group to create lightweight, intelligent and autonomous mobility solutions for people and goods. PFF's first product is Gita: a smart, nimble, cargo vehicle designed to match the full range of human mobility, with speeds that extend from a crawl to a sprint and a zero turning radius. The Gita models are cylinder-shaped with two rubber tread-like wheels at the outer edges. Each unit has a storage area enclosed between the wheels. Gita can roll up to 22 miles per hour and uses various cameras and sensors to navigate. It operates inside and out, on sidewalks and streets, just like a person. Gita is the first in a portfolio of PFF vehicles that are in development.

Our personal belief is becoming a commercial good. How will we create value with these technologies?

Common sense is commonly defined as the obvious truth, but that is not correct. Scientists have shown that common sense is what we think that most people in our reference group believe or do – not whether that belief is factually true, or whether that activity makes sense. This scientific insight made new business models possible.

One of the puzzles of the success of the social media platforms such as Facebook is that its users are so careless about revealing private or even intimate information about themselves. Who could have predicted in 2004, on the evening of the founding of Facebook, that eventually one quarter of the world's population would entrust to a publicly accessible website much of their private information: who their friends are and what they think about them, where they go on vacation, what they like to eat and much more. Moreover, these users would provide all this information for free to the website, and then let this company make considerable profits with this information. The reason why this impossible prediction became possible reality, is because it became common sense to use Facebook.

Duncan J. Watts was a professor for sociology at Columbia University before he led the research group Human Social Dynamics at Yahoo Inc. Since 2012 he is a Principal Researcher at Microsoft and Professor at Cornell University. In 2011 he published the book *Everything is obvious once you know the answer*. In this book he revealed that the detailed data which the information giants such as Yahoo obtained from their users allowed these companies not only insights into predicting individual behaviour, but also allowed them to predict how entire societies function. Duncan J. Watts has a PhD in theoretical and applied mechanics. He switched to sociology, because he found that with the new data generated by the information companies it is possible to understand the rules of social interaction with mathematical models.

One of his main insights was that one of the foundation theories of sociology turns out to be wrong. This foundation theory is the existence and role of the trendsetter in society. According to this theory, certain persons in society would have the ability to start a trend – whether these are charismatic speakers, cool artists, influential journalists or rich or powerful individuals – their behaviour and preferences would set a trend which will influence everybody else over time. Therefore generations of marketing gurus and public relation professionals have been hunting after these trendsetters in order to either seed or identify the next big thing. With the data from the social networks Mr Duncan Watts was able to show that this theory is plainly wrong. There are no such persons who are trendsetters. At best persons with a high public profile are amplifiers of trends, but surprisingly often, they are not even that. The recently created job called *Influencer*, fulfills this function: being an amplifier. The data proves that trendsetters do not exist, and that the theory is wrong.

A society functions with many different functional models, and not all of these models have been discovered yet and cast into mathematical formulas. But there are some common themes to those mathematical models which have been discovered. One of the themes is that the *objective* truth is by far less important compared to how many people in the reference group *subjectively believe* what is

true. If enough people believe in a subjective truth, no matter how far apart from factual evidence, then the objective truth becomes nearly irrelevant.

The other theme is that the origins of such subjective truths are often related to deep-seated emotions of either negative nature such as frustration, anger or despair about a situation, or positive nature such as joy, euphoria and empathy. Another theme is that human beings are not nearly as rational as we think of ourselves. Typically our brains will make a subjective decision in its subconscious emotional centres, and then post-rationalize this decision in its conscious processing areas. The post-rationalizing makes us think that we made a rational and senseful choice, but in reality the choice was already made beforehand by our subconscious emotions and intuitions. These typical behaviours can be modelled mathematically and be used to forecast how a society or a community reacts and arrives at collective decisions.

Professor Serge Galam from France is considered the father of the scientific branch called sociophysics, which similar to Duncan Watts, explains social phenomena with mathematical models. One of his models describes how frequently held but non-expressed prejudices in a society can influence elections. With his mathematical model he has been correctly predicting political outcomes since several years, including Brexit. He also published the prediction that, based on his mathematical models, Donald Trump would win the election – as early as in August 2016. This was at a time when virtually all poll results forecast a decisive victory for Hillary Clinton.

Prof Galam observed in his data that with every targeted emotionalized message, Mr Trump awakened deep seated prejudices in US society which he then capitalized over time into votes.[48] Here is the mathematical formula of the voting function which Prof Galam applied to the US election of 2016:

$$P_r(p_0) = \sum_{m=N\left[\frac{r}{2}\right]}^{r} \binom{r}{m} p_0^m (1-p_0)^{r-m} + k\delta\left[\frac{r}{2} - N\left[\frac{r}{2}\right]\right]\binom{r}{\frac{r}{2}} p_0^{\frac{r}{2}} (1-p_0)^{\frac{r}{2}},$$

Scientists such as Duncan Watts or Serge Galam begin to master a technology that is changing the world. This technology is capable of creating common sense – of creating communities of believers in what everybody else believes. This used to be the task of the marketing and branding experts. Will they keep this function?

It is possible to develop many questions around the ethics of such technology. Political scientists lead heavy debates whether these technologies – which are being formulated by scientists such as Serge Galam or Duncan Watts and exploited by firms such as Cambridge Analytica – are beneficial or malicious for the political, social and physical health of a society. How much does the creation of a common sense belief cost today? 10 million USD, 100 million, 1,000 million? Can the New York Times' Frightful Five – Google, Facebook, Microsoft, Amazon and Apple, or any other determined individual or company with sufficient financial means – make society want to have intelligent toilets for instance? Can they make societies want to sequence their genome and hand over the information voluntarily to them, and for free? Can they make society accept synthetically enhanced DNA for, animals such as brainless chickens and ultimately also performance-enhanced human beings? Can they make societies accept or welcome such decisions even if the members of these societies were initially opposed? The Frightful Five have a combined stock market valuation higher than the GDP of the United Kingdom and almost that of Germany. If they become convinced of a business model, then paying USD 1 billion for something – in light of a combined stock market value of USD 3 trillion – is easily affordable.

[48] Serge Galam 2016: The Trump Phenomenon, an Explanation from Sociophysics, CEVIPOF, Centre for Political Research, Sciences Po and CNRS.

10. Conclusion and next steps for the Food&Ag decision maker

Today's global citizens have perhaps unknowingly entered into a deal where the full implications are only now becoming clear: it is appreciated and has become an indispensable part of modern life that the Google search function is free of charge, that Facebook facilitates social life free of charge, and that Amazon provides product recommendations free of charge. But this does not mean that it is free of cost. Our beliefs are deeply shaped by the common sense of our reference group, be it analogue or digital. Does it become even harder to tell fact from opinion in a digitally connected world? Definitely, and we observe a continuously rising speed of messages spreading. But this is our true investment here: In contrast to the processes of developing sense and meaning in society, which are still predominant, we have adopted a new kind of actor in the digital world: data-rich firms that sell services and nudge the consumer in a profitable direction for them. May be reality has already moved a step further: A limited number of commercial companies may already be developing - and running the algorithms which lead individuals to the impression: *This is what my group holds true*. The result: Personal beliefs are becoming commercial goods.

Tristan Harris created an app called Apture which was supposed to explain complex concepts to online readers. His start-up was purchased by Google in 2011. After a while Google created a job for him called Design Ethicist and Product Philosopher. In 2016 he left Google and became a warning advocate that digital technology diminishes the human capacity to make free choices.

> Tristan Harris, former Design Ethicist at Google:
> *Whoever controls the menu, controls the choices. The news we see, the friends we hear from, the jobs we hear about, the restaurants we consider, even our potential romantic partners – all of them are increasingly filtered through a few widespread apps, each of which comes with a menu of options.*[48]

It is useful to consider that not all technology changes that are possible, will actually happen. By the same token, many developments which are considered impossible, might very well happen – as became the fate of Nokia, Blackberry and MySpace.

This analysis started off with the observation of significant developments in four areas of technology, which currently experience rapid change and explosive growth in applications. Each of them has the potential to deliver large productivity advances to supply the world's demand for better food, which would be much welcomed. These four areas are:

1. Genomics/genetics: low cost and common availability of individual genomic DNA sequencing, in addition to replacement of natural DNA with synthetic DNA,
2. Software/data analytics: ubiquity of artificial intelligence computing,
3. Machinery: autonomous machinery for real-time data analysis and last-mile product delivery,
4. Social Engineering: data-driven digital communication methods deliberately forming public opinion.

The development and application of each of these four technologies raises profound ethical and moral questions which need to be answered. Given the speed of development and considering the global need for a rise, or rather, a big leap in productivity in agribusiness, we neither expect a profound ethical consensus before introducing these technologies in global markets, nor can we hope for that. The processes of discussing their potential for feeding earth's people and a prosperous agribusiness as well as the changes introduced through their implementation, will of course influence the precise use cases and factual use of these technologies. But with the growing potential of artificial intelligence, the ubiquity of genetic analysis and design and the need to increase the production of food globally we have all the ingredients for a strong and exponential development.

We asked 34 senior decision makers in the Food & Ag industry about the weighting of which activities will drive value in their business. We gave them four choices:

a) Managing the physical flow of goods and services (purchasing, manufacturing, selling, business operations...)
b) Acessing and managing finance (credit management, financial compliance, auditing, financial engineering...)
c) Creating actionable data (data management, IT, copyrights, data access...)
d) Creating ethical legitimacy and consumer preference (branding, labelling, stakeholder management, CSR activities...)

The result of the survey was that these managers expect that in 10 years time, in 2027, 32% of the value in their business will derive from actionable data, and 30% to derive from creating ethical legitimacy and consumer preference. These values are up versus 24% and 24% in 2017, and 14% and 15% respectively in 2007.

Each business will need to find its own path towards this future where value chains may be reshuffled in unexpected ways, and value creation may occur in very different ways. Our three recommendations, which we believe are universal for any business across the Food & Ag industry, short and crisp:

- Engage your stakeholders concerning the ethical dimensions arising from application of products and processes from these four technology areas, and develop guidelines for using or not using such technologies.
- Start becoming acquainted with artificial intelligence and implement AI systems in your business models. Welcome and integrate these systems in your work force, as if hiring a new type of employees. AI systems are in many ways more similar to human workers, than to machines.
- Invest in the change capacity of your company. Too many companies and industries have found out that they must change and then were too late about it. It is inherent in the dynamics of business disruption that it is nearly impossible to tell when and where it will happen. The best way to be prepared is to be prepared.

Exhibit 13 Survey Results

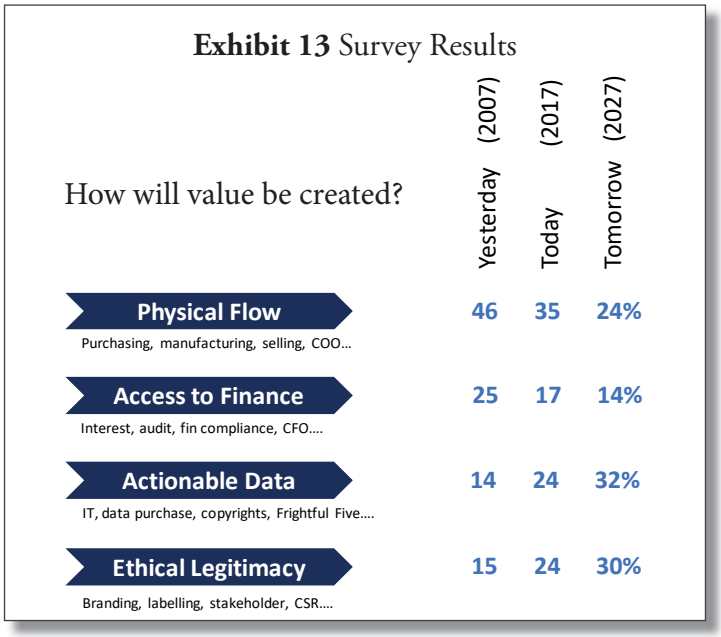


Exhibit 1
United Nations, Department of Economic and Social Affairs, Population Division (2015). *World Population Prospects: The 2015 Revision. Key Findings and Advance Tables*. Working Paper No. ESA/P/WP.241. New York: United Nations

Exhibit 2
Agricultural Development Economics Division, Food and Agriculture Organization of the United Nations (FAO): *Worldwide agriculture towards 2030/2050 – the 2012 Revision*, Nikos Alexandratos and Jelle Bruinsma, Global Perspective Studies Team, page 8

Exhibit 3
Atomic

Exhibit 4
National Human Genome Research Institute; CEIBS analysis

Exhibit 5
University of Wisconsin-Madison

Exhibit 6
Alan Meeker

Exhibit 7
Nine intelligences according to Gardner

Exhibit 8
Description Neuralink according to their website

Exhibit 9
Listings as per 28 August 2017

Exhibit 10
Emily S Cassidy, Paul C West, James S Gerber and Jonathan A Foley, Redefining agricultural yields: from tonnes to people nourished per hectare, 2013 IOP Publishing Ltd

Exhibit 12
Startech; Piaggio

Exhibit13
CEIBS Food & Agribusiness Seminars

www.ceibs.ch/2027
www.foodandagribusiness.org/2027

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