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Jannick B. Pedersen; Anders Hvid

Face the Future

What disruption and exponential acceleration means for you?

JANNICK B. PEDERSEN, ANDERS HVID

FACE THE FUTURE

WHAT DISRUPTION AND EXPONENTIAL ACCELERATION MEANS FOR YOU?

Face the Future: What disruption and exponential acceleration means for you?
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FOREWORD BY SALIM ISMAIL

Reaping the benefits of exponential growth is the greatest opportunity in history. This task is too large and important to be left to a selected few! Instead we should rally entire societies and populations - both to counteract fear of change and to share the tremendous benefits from exponential acceleration of our technological abilities.

In their book, Face the Future, the authors succeed eminently in making the coming changes and opportunities comprehensible to a larger audience. By coining new terminology like “creative crossings” and tools like the “Exponential Curve Explorer” they equip the reader to think innovatively and create new solutions and businesses - by pairing what they know with emerging exponential technology such as Artificial Intelligence, Robotics and much more.

A special pleasure in the book, is the eloquent chapter on 3D Printing by their co-founder *Märtha Rehnberg*. In just a few pagers, you are given a tour-de-force of one of the most interesting technologies currently changing our industrial mindset.

Personally, I have spent the last decade engaged in the same endeavor of sharing this fountain of knowledge – both as a Co-founder of Singularity University and as author of Exponential Organizations.

I welcome Jannick, Anders and Märtha as co-inspirators in this daunting, but very satisfying task.

Please read this book carefully yourself – but do share the content with your peers, spouse and children. You will want them to absorb the concepts and terminology to understand the future - and the tools to thrive and make their own creative crossings.

Salim Ismail

INTRODUCTION PAY ATTENTION! THIS IS IMPORTANT!

We say this to our children, but it often falls on deaf ears. That's because everything is important! The same thing applies for technological breakthroughs. We're constantly bombarded with news about new technologies that could either give us a bright new future or wipe out the entire human race. We have become desensitized to these proclamations. This notwithstanding, we're going to go out on a limb with this book… because it is important! The world as we know it is on a path towards an unprecedented acceleration of change – and it's well worth your while to understand why and how this is.

We have both been fascinated by technology all of our lives, and exploiting technology and technological developments has always been an integral part of our work. We revel in the speed and diversity with which technologies evolve and have not shied away from making bold predictions about the future. However, it was through our encounter with Singularity University that we both discovered the explanatory power of the exponential perspective and how it has spread from computers and networks to a number of other fields. Since then, we have worked to heighten awareness of exponential growth and to embed an informed debate in society at large. Exponential technologies represent both an opportunity and a threat for societies and companies, and we have both given numerous talks on this topic both in Denmark and abroad.

We consider advances in technology to be a source of wealth and peace and we endorse missions aimed at using technology in order to create positive impact. On a somewhat smaller scale, Jannick organized a 24-hour, 24-speaker conference for top executives entitled "The Year 2020", and has established himself as a well known advocate for impact investing. Additionally, Anders founded an idea impact competition, now under the name Founders of Tomorrow, that has been running since 2014. Almost 300 selected participants have, over the last four years competed with projects that could positively impact a billion people, and every year, a winner was found to win a scholarship to the likes of Singularity University. Founders of Tomorrow is now a yearly event and has been expanded to incorporate a larger educational component in order to train all participants in exponential thinking for a full week.

As part of our mission to heighten awareness of exponential growth, we have started a think tank business – DareDisrupt (www.daredisrupt.com) – where we monitor technological developments in a wide range of industries, help established companies to interpret their technological reality, and facilitate innovation processes based on disruptive technologies. Today DareDisrupt consists of three branches: Advocacy, our future speaking agency, last year Advocacy delivered impact talks for 1.500 students; Academy our educational arm teaches technological intuition through workshops and events; and Consulting where we help businesses design impactful strategies for the future. Our goal is to empower a million minds, to see a million possibilities and solve a million problems.

In this edition of Face the Future we have received help from Märtha Rehnberg. Märtha is Co-founder of, and Partner at DareDisrupt and Co-founder of BLOC (Blockchain Labs for Open Collaboration). She is a trained political economist and published expert on 3D printing, the future of Global Value Chains and consumption. Märtha has written the chapter on 3D printing and further contributed with the general upgrade of this book.

Jannick B. Pedersen holds a Master of Science degree in Macro Economics and is Co-founder and Chairman of the Board at DareDisrupt and Franklin Covey Denmark. He is a serial entrepreneur and an active business angel focusing on impact investing. He has attended several programs at Singularity University and for the last couple of years, he has been focused on a new book on Anti-age: The effect of exponential technologies on longevity.

Anders Hvid holds a Master of Science degree in Sociology and is Co-founder and CEO of DareDisrupt. He is a Singularity University Graduate Studies Program 2010 alumnus and former Adjunct Faculty Member. Additionally, Anders is part of the Sirikommissionen, a governmental initiative on how Denmark should leverage new tech- nologies and disruption strategies, to benefit our future livelihoods and create new jobs. He is also the co-author of a new book on the application of exponential technologies in the municipality sector.

1 FACE THE FUTURE

Humanity has continuously evolved: from hunter-gatherers to agrarian societies; from industrialization to today's Information Society. Since the dawn of time, we have strived to improve our circumstances with the aid of technology, and each transition from one stage to the next has brought with it new narratives, new ways of organizing ourselves, and new political power hierarchies. The most significant difference between then and now is the speed at which things are changing. Homo sapiens spent 200,000 years as a hunter-gatherer. The rate of change during this period was so slow that changes were not noticeable by any single individual. Generation after generation we repeated ourselves. Re-created what we had learned from our forefathers.

12,000 years ago, the Agricultural Revolution spread and supplanted hunters and gatherers over a period of a couple of thousand years. However, the Agricultural Revolution had more far-reaching consequences than just a new way of producing food; it brought with it towns, specialization and new technologies. Technological development consequently had a big impact on how we organized ourselves.

A mere 200 years ago, people's lives were transformed yet again by the technologies of industrialization. Industrialization meant using the power of machines instead of manpower, and the introduction of chemical production processes. The Industrial Revolution was a major milestone in our history and changed almost all aspects of people's daily lives. For the first time in history, the population as a whole experienced sustain improvements in its standard of living. Industrialization also meant explosive population growth, the organization of labor, and the establishment of city societies as we know them today.

What we today refer to as the Digital Revolution began sometime between the 1950's and the 1970's. This revolution represented the transition from analogue, mechanical, and electronic technologies to digital technologies. The first digital computer was developed during this period. During the 1990's, things went to the next level when the Internet became ubiquitous. The Digital Revolution, with the computer and the internet, has brought us to what we today call the Information Society. The Information Society has created a knowledge-based society which is important in itself and which has also had a significant impact on both the manufacturing and service sectors by, among other things, enabling the optimization of manufacturing processes and providing a foundation for mass customization.

However, the most interesting aspect of these developments is neither the Information Society nor the Knowledge Society: it's the digitization! Digital products have a number of characteristics that set them apart from the physical products we are familiar with today. A digital product can be replicated ad infinitum without any loss of integrity and can be transported to the other side of the world in a matter of seconds. Finally, the relationship between price and performance for digital products can be expressed by an exponential function. We have discovered that the number of calculations that can be performed by a computer (for the same price) doubles every second year. The smartphone in your pocket today is already several thousand times faster and over a million times smaller and cheaper than the world's fastest computer was in 1968. Realizing this is essential to understanding the evolution of digital products today.

A plethora of technologies are beginning to benefit from this development because they, too, have gone digital! This includes robots, artificial intelligence (AI), biotechnology, and 3D printers. By going digital, they can take advantage of the enormous computational power that digitization brings to the table. And when digitization becomes the driving force, things go exponential.

But exponential growth is difficult for people to understand intuitively. We overestimate the rate of change in the short term and underestimate it in the long term. We see possibilities and are thrilled in the short term, but overestimate the consequences. Three years later, we are disillusioned and discard our projections, only to be taken completely by surprise 10 years further down the road when change hits us like a freight train.

AI is part of this development. AI is the ability of machines to make decisions based on input from their environments. Our ability to manufacture small, digital, and intelligent entities that can communicate with each other has now reached the stage where we can both embed and activate them in all the physical objects we surround ourselves with. The world we live in is awakening.

In the future, things around us will no longer be dumb and passive. They will begin to do our bidding and may even take the initiative on our behalf. The Digital Revolution in itself encompasses more than just the Information Society. This new era will be intelligent. We call it the Age of Intelligence.

At the first stage, your washing machine will start washing when there is a surplus of energy on the grid and the thermostat will turn on the heating when you approach your home. At the second stage, we will see somewhat more complicated things such as self-driving cars or digital bank clerks. At the third stage, your smartphone will notify you that you are about to become depressed or manic, and may even initiate treatment…

The same thing applies to biology. In the first phase, digitization makes it possible for us to visualize and understand correlations in extremely large datasets. We can "feed" an AI with so much knowledge and so many research results that it will be superior to any doctor at making diagnoses and developing therapeutics. In the second phase, we can start to manipulate human DNA, and in the third phase, we can print new organs in a 3D printer and manufacture nanorobots that repair the human body from the inside…

In particular, the ability to manipulate DNA, the building blocks of life, makes for some very interesting perspectives. As a hunter-gatherer, mankind lived off Nature. In the Agricultural Revolution, we learned to tame and control Nature's fecundity through cultivation. For industrialization, it was no longer sufficient to control: we started to form Nature. Digitization enables us to take the next step: we are now in a position to mold Nature.

Change has always been met with open resistance because it often eliminates people's livelihoods. Consider how a coachman must have experienced industrialization and a typesetter digitization. But the rest of us, who won't necessarily become redundant to start with, are also hesitant, presumably because the changes encompass more than just the technological advances. Incumbent institutions, such as political and religious hierarchies, cannot cope with the complexity that the new technologies introduce. Because of this, the new technologies can often be considered a threat to the very foundations upon which our society is built. We hope that this book will provide you with a perspective from which to view technological developments – developments which will have a massive impact on our future. Not just in the guise of cool gadgets, but as fundamental changes to education, the workplace, and healthcare.

In the first part of the book, we explain the switch from linear to exponential growth. An understanding of exponential growth is the key to understanding the digital revolution, and is a central feature of the era we are entering.

In the second part, we describe developments within the fields of information technology, AI, 3D printing, biotechnology, and nanotechnology. We will describe current developments in each of these four fields as well as the disruption they will cause.

In the third and final part of the book, we will look at the implications of the technological developments for a number of key areas such as education, the workplace, the energy sector, and healthcare. We will also describe how technological developments led to the demise of Kodak and created new markets for companies such as Netflix and Amazon.

The book is primarily concerned with technology and, to a lesser extent, with the people that will use it. Our mission is first and foremost to make exponential growth visible and intuitive for the reader. By so doing, we hope to establish a framework for the subsequent, and very important, discussion of how we should face the changes.

Happy Reading!

PART 1
INNOVATION AND THE EXPONENTIAL PARADIGM

2 INNOVATION: PAST, PRESENT AND FUTURE

He stood by the large beech tree at the edge of the settlement. Deep in thought. They hadn't had a successful hunt for months and everybody was tired of eating only whatever could be foraged. Maybe the forests to the north held more game, but the journey would take many days, and they couldn't manage it if they didn't have fire with them. That, on the other hand, was a problem he could solve.

He cut a large piece of tinder fungus from the beech tree at the edge of settlement and went back to the cooking fire. Here he removed the outer skin of the tinder fungus and placed the porous pulp in the warm lye. When the pulp had absorbed the fluid, he hammered the pulp flat and laid it out to dry in the sun. By midafternoon, it was bone dry. He then cut it into small pieces, set fire to them, and tipped them into the birch bark container.

Now he had portable fire – for the long journey towards a better future!

Innovation

Mankind didn't invent fire but we did tame it. Building upon thousands of innovations, our forefathers invented useful things such as the campfire (for light, warmth, and protection), the torch (a portable source of light), the cooking fire (for efficient cooking), the stove (for space heating), and the furnace (for smelting).

Some of these innovations were radical. The torch, for example, enabled us to move about at night. But most innovations were small, continuous improvements – incremental improvements – such as the fastest way to start a campfire, the best way to tend a birch bark container so the embers lasted as long as possible, and the best way to build a chimney to minimize the amount of smoke from the fire.

It can be instructive to consider innovation as either being radical or incremental, although in reality, it's a continuum. A radical innovation positions a company way ahead of its competitors. This advantage makes it possible to earn abnormally large profits, at least in the short term, and this period can be extended by incremental innovation – small, continuous improvements. The honeymoon ends when a competitor is also successful with a radical innovation of its own. Consider, for example, Nokia, Apple, and the evolution of the smartphone.

Necessity is the mother of invention in the same way innovation is driven by the dream of success – but innovation is also driven by human traits such as curiosity and the creative urge. The economic rewards and defense against the competition are sufficient reasons and incentive enough for companies to invest in innovation. But there are additional good reasons to do so. A company that focuses on innovation will attract the most creative employees. The economic rewards that accompany successful innovation will therefore become a badge of success and not a goal in itself.

It is easiest for us to think of innovation in the context of a new or significantly better (physical) product that is manufactured by a company. But innovation is not just restricted to physical products. We can also innovate processes and procedures. The term "social innovation" further broadens the definition to encompass the management and organization of companies as well as the creation of new and more effective organizations within healthcare, education and public administration.

The thinkers

We owe much of our current understanding of innovation to three extraordinary individuals.

The Austrian economist Joseph Schumpeter is often credited with having framed the concept of innovation (1934). He insisted that innovation must have economic value if the innovator is to be worthy of the name, but at the same time he called innovation "creative destruction."

Management consultant, educator, and author Peter Drucker identified "the unexpected" as the first of seven sources of innovation (1985). What did not go according to plan? What opportunities do we now have to do things differently?

Clayton Christensen, a professor at Harvard University, introduced the concept of disruptive innovation (2002). Disruptive innovation does away with the status quo by creating something new and more appealing. One of the more interesting aspects of Christensen's theory is where he describes the danger of a company becoming entangled in the relationships between its customers, employee competencies, and suppliers. New competitors can take over a market by using disruptive innovations to make products or services available to customers that previously either couldn't afford to buy them or weren't sophisticated enough to use them. In other words, customers that weren't important for the existing players. As the technology gradually matures, however, the new competitors' products will also become attractive for the existing players' customers, thereby putting the existing players in a particularly difficult situation.

Christensen uses the development of the market for computer hard disk drives as an example. What's interesting about the case is that the existing players are not being threatened by any kind of technological quantum-leap: it's something as trivial as the reduction in size of the drives. The possibility of manufacturing smaller disk drives was not important for the existing players, which meant that the new competitors could easily establish themselves in this market with completely new customers. The performance of both the new and the older formats improved faster than the customers' needs. Soon the new, small drives met customer expectations and the secondary consideration of size suddenly became the deciding factor in choosing a drive. The new competitors took over the old customers and made the established manufacturers redundant.

And this isn't just a theory. The newspapers are full of stories about disruptive innovation in established markets. New mobile payment solutions, armbands that monitor your health, et cetera, et cetera.

The process

Innovation, by its very nature, cannot be reduced to a formula, but we can choose between different approaches. We can do it in isolation (the lone genius), in collaboration with others (open innovation), or even more decentralized (user-driven innovation). One could say that we are shifting from product development to co-creation.

One example of the power of user-driven open innovation is the growth of the internet from when the first website was published (in 1991) to today. In 1991, a British physicist at CERN, Tim Berners-Lee, needed to be able to share documents with others, so he developed the Hypertext Transfer Protocol (HTTP) web technology to solve the problem. Did he make any money out of it? No, but he set in motion a user-driven innovation process that continues to grow explosively to this day.

User-driven innovation can be extremely powerful and the growth of the internet is probably the best example there is. The internet is, architecturally speaking, a “dumb” network. The intelligent solutions are built at the edge by us, the users. We have experienced a veritable explosion of new concepts, services, and business models, all based on the internet infrastructure. With an expected six billion people finding their way to the internet before 2020, the opportunities for exploiting this source of “super-intelligence” will increase.

Author and opinion leader Chris Anderson describes it as an “innovation explosion”, driven by the sharing of information through videos uploaded to sites like YouTube, where more and more people share insights and creations and inspire each other.

And we aren’t just talking about uploads from self-taught musicians and inventors: even researchers are now breaking out from the traditional but slow and restrictive publication channels. JOVE (Journal of Visualized Experiments) publishes research results in the form of short, instructive videos. JOVE’s mission is precisely to increase the productivity of scientific research.

There are countless examples of where engaging the users is an integral part of the business model. One such area is financing ideas for new companies: crowdsourcing. You not only get money to develop your product; you can also validate whether it’s relevant for your future customers. Other solutions enable users to share their worldly goods with each other: a spare bed, a lawn mower, or even their car.

Technology-driven innovation

This book's primary focus is technology-driven innovation; more specifically, technologies that grow exponentially. This does not imply that processes, customer needs, market development, etc. are irrelevant, but we will focus on the ever-growing "space of opportunity" that technology creates.

Innovation is an important part of our lives; we can't help trying to improve one thing or the other during the course of a normal day. But we do so from a predominantly linear perspective, even though we live in an exponential world.

In what way does innovation change in a world that is exponential? Keep that in mind as you read the following chapters. We will present our answer to that question in the last part of the book.

3 SWITCHING THE PARADIGM TO EXPONENTIAL GROWTH

Our world is undergoing a transformation. From having been local and linear for thousands of years, it's now both global and exponential. The objective of this chapter is to make you really feel the paradigm shift in going from linear to exponential thinking. And in order to ensure that you literally can feel it, we are going to chain you to a seat in the uppermost tiers of a stadium and try to drown you. But before we do that, a short introduction…

We talk about paradigm shifts when our understanding of something or other changes radically. Some paradigm shifts can be like an epiphany while others can be very painful. A paradigm shift typically results from the realization that a new way of doing things would be more appropriate. These new ways of doing things will lead to new results, and therefore real change. In other words, changes in attitudes lead to changes in the way we do things, which in turn lead to different results. The consequences of a paradigm shift can be quite extreme. In many ways, we can claim that industrialization, when viewed as a paradigm shift, led to urbanization and the educational and democratic institutions that we have today.

If we believe that the Earth is flat, then we will have little or no desire to sail too far out towards the edge: the risk of "falling off" will be too great. On a flat Earth, nobody would be interested in financing a sea voyage, and any sea captain struck with wanderlust would consequently have difficulty finding backers. But if our world view changes to that of a round Earth, then suddenly a sea voyage doesn't seem so dangerous anymore. We ought to be able to count on coming back home if we just sail far enough, right? The paradigm shift from the flat to the round Earth took place over several hundred years, and was one of the reasons why longer sea voyages could be financed. These journeys led to fantastic discoveries and made the involved parties very rich. This in turn led to more trade, economic growth, the rise of limited companies (for shared ownership of ships), the introduction of exchanges (to facilitate the sale of ownership of the ships), and the start of globalization which is still going strong.

The flat Earth is a historical curiosity that we can afford to smile indulgently at today, but major paradigm shifts occur all the time. Take, for example, our brain. Hardly a month passes without some researcher presenting new insights into how the brain functions, and why we do what we do. We're often only paying attention half the time, so perhaps we haven't noticed the following significant paradigm shift.

We have been told – we don't remember exactly by whom – that a fully grown brain has a finite number of cells and that they slowly die as we grow older. That is, if they don't die faster during a weekend binge! This paradigm may have kept us from drinking too much alcohol during our youth. Maybe. Either way, we felt bad about our brain every time we had a hangover!

New research shows, however, that we generate new brain cells throughout our entire life. And in particular, that we generate new brain cells whenever we exercise. Physical activity causes, quite simply, new brain cells to be produced. How do we view the relevance of exercise within this paradigm? We have long known that we ought to exercise more, but suddenly we have a much clearer picture of the "return on investment". Even more recent research indicates that new brain cells die if we are not engaged in learning. How do we view the relevance of lifelong learning within this paradigm?

William Gibson said in 1993: "The future is already here – it's just not evenly distributed." The same thing applies to paradigm shifts based on new research and insights. When the flat Earth paradigm was replaced by the round Earth paradigm, people didn't suddenly start sailing around the world or financing sea voyages. New insights diffuse slowly.

Today, because of the internet, ideas spread much faster than before. On the other hand, there is now so much new knowledge that today's World "knowledge map" is essentially one big white spot, just like the map of Africa was in Livingstone's time. Not only is the amount of knowledge growing rapidly, we share this knowledge so much faster as well. Research results from a university in Australia can be made globally available as text and video the same day the project is completed.

We are "African Explorers" again, armed with a map of Africa covered with large blank areas. We explore and are amazed by all the discoveries we make on our way through the internet jungle.

Exponential growth as a paradigm shift

One of the most important concepts which, this notwithstanding, is often misunderstood, is the concept of exponential growth. We've probably heard of Moore's law and we may have learnt how to calculate compound interest, but exponential growth is the key to understanding the remainder of this book and, not least, our future.

Both of us have given many talks in recent years about future trends, and we often ask the audience to perform a small task in order to test their understanding of exponential growth. Irrespective of whom the audience is, our experience has been that the vast majority are surprised by the result.

> Come with us into Levi's Stadium in Silicon Valley, all the way up to the highest tiers. Here, you are chained to a seat with a good view, but with no means of escaping. Beside you is a water tap.
>
> You are a bit concerned about what's going to happen now because you have just been told that the stadium will be filled with water according to the following formula: one drop of water (1 ml) during the first minute, two drops of water during the second minute, four drops of water during the third minute, etc. By the way, we have wrapped the entire stadium in plastic so no water can leak out…
>
> It takes approximately 7 days to die of thirst and 30 days to die of hunger. You know you won't die of thirst after 7 days because we have placed the dripping tap right beside you.
>
> The question is: will you die of hunger – or will you drown?
>
> You drown, of course! Otherwise we wouldn't have asked you the question. But approximately how many days will it take to fill up the stadium with water?
>
> Two days? More?

The correct answer – accurate to within one or two minutes depending on the exact size of the stadium – can be found at the end of this chapter.

The next, and equally important, question is: when will you realize that you have a serious problem on your hands?

Presumably, only when the football field is covered with water – and that will only occur after 80% of the time has elapsed! Most of the time you can't even see the water, and even when a puddle does appear, it won't look particularly threatening. When you finally figure out the relationship between the height of the water and time, it'll be too late to do anything about it. This is a thought-provoking and frightening realization.

The moral of the story is that we must all – as individuals, compa- nies, and society as a whole – start being more proactive about the future than we have been. If we wait until we can see that the situation is getting critical, it will often be too late.

Is exponential growth a new concept? No, but from being a mathematical curiosity, it has suddenly become essential for most of us to understand these exponential curves. According to inventor and entrepreneur, Ray Kurzweil, exponential growth is "the nature of order" in the context of developments within information technology.

A rule of thumb and a couple of examples

Exponential growth is used to describe the amount of something that increases by a constant factor over time. If you can get 3.5% in interest from your bank, how long will it take for 100,000 dollars to increase to 200,000 dollars? Unless you have studied statistics, it can be difficult to see beyond the first couple of years. How long will it take before the amount has doubled?

Here's a simple rule of thumb. The doubling time is equal to 70 divided by the rate of growth. In our example, the doubling time is equal to (70/3.5) = 20. In other words, it takes 20 years to double the original amount. 20 years is such a long time that we don't consider the growth to be exponential but linear.

The most well-known example of exponential growth is the legend about the origins of the game of chess. It is told that the king was so delighted with the game that he permitted the inventor to name his price. The inventor, who was quite clever, requested that one grain of wheat be placed on the first square, two grains on the second square, four grains on the third square, and so on. The king, who had no real understanding of the exponential function, almost felt insulted by the investor's humility and ordered that the grains of wheat be counted out right away. The inventor received 1, 2, 4, 8, 16, 32, 64, 128, 256, and 512 grains for the first 10 squares, respectively. 10 doublings gave a thousand fold increase of the original amount. After 10 more doublings, they reached one million grains: after 10 more doublings, one billion grains.

If the king were, in theory, to carry out his promise (because it can only be done in theory), then he would have had to hand over 18,446,744,073,709,551,615 grains of wheat. That corresponds to 461,168,602,000 metric tons of wheat or a mountain of wheat bigger than Mount Everest. Or over 1,000 times more than the entire global production of wheat in 2010.

Even though at first glance, it just appears to be an entertaining anecdote, we should keep in mind that this is the way the world about us changes. It is this principle of exponential acceleration upon which any predictions of the future we make should be based. And, just for the record, we are far from being the first to point this out.

Let us present three people that all have made exponential growth a central theme of their work.

Robert Malthus

300 years ago, Robert Malthus made a shocking discovery: the human race was going to die of starvation!

This would come about because the population was growing exponentially while food production was only growing linearly. At some point in time, we wouldn't be capable of feeding the growing population and only starvation would keep the population growth in check. Spreading this message was so important for him that he updated his famous "An Essay on the Principles of Population" six times over the course of 30 years. What Malthus didn't foresee was that we would discover ways to increase food production – so it, too, grew exponentially – and that we would also invent ways to limit the number of childbirths.

But the specter of overpopulation has not gone away. Reducing population growth has been a key goal for foreign aid programs. When the number of people on the planet surpassed seven billion in 2011, the media were yet again awash with overpopulation doomsday scenarios.

Gordon Moore

Probably the best known of the three people is Intel engineer Gordon Moore and his conjecture about the growth of computing power. In 1965, Gordon Moore, who was one of the foremost integrated circuit designers at the time, and who would later become the chairman of the board at Intel, observed that the number of transistors that could be put on an integrated circuit doubled every two years. This conjecture has been confirmed numerous times since and has subsequently been dubbed "Moore's Law."

It's somewhat amusing to note that Moore himself, back then in 1965, predicted that his "law" would only hold for 10-15 years. Today, almost 50 years later, it still holds, but Gordon Moore is still skeptical. As recently as 2011 he repeated that it won't last forever: *'There is a physical limit to how thin the semiconductor layers can be. Today we're fabricating gates that are five molecules thick. But we can't go below a molecule in thickness: that's the end of the road'* says Gordon Moore.

Ray Kurzweil

But it won't come to an end, if we are to believe Ray Kurzweil. "We just switch to a new technology paradigm," according to Ray Kurzweil, who has spent many years extrapolating developments in technology and making rather precise predictions about the future.

In his book "The Singularity is Near", he describes how the processing power of computers has grown exponentially during the past 110 years while simultaneously going through five technological paradigms. When a technological paradigm (for example, the integrated circuit) runs out of steam, a new one takes its place. So even though a given technology may follow an S-curve-like trajectory and end up plateauing, the concatenated sequence of S-curves will trace a beautiful exponential curve.

Consequently, Ray Kurzweil predicts that the exponential growth will still hold; that the performance-to-price ratio will double every year. Furthermore, the rate at which these paradigm shifts are occurring is also increasing exponentially, he says. In the first half of the last century, the performance-to-price ratio doubled every three years, in the second half, it doubled every two years; now it's doubling every year.

But there's more. Ray Kurzweil hammers home the most important conclusion: that increasingly more technologies will "go digital" and thereby grow exponentially. It is all these simultaneous exponential growth trajectories that give rise to completely new perspectives for the future.

But how can it be that the processing power of computers has grown exponentially during the past 110 years, and that the computer itself has gone through a technological evolution consisting of five completely different technology paradigms? If we are to believe that the growth will both continue and spread to other areas of technology, we must try to understand why that is the case.

What if investments in new technologies were primarily driven by what goals one expected to achieve? That we believe that we can double the memory capacity of a hard disk or the number of pixels in a digital camera? Right! Then we'll allocate the necessary resources to achieve it. Moore's law then becomes a self-fulfilling prophecy. If we believe that our competitors are following the curve, then we had better do so too. If we fall behind, we need to shake up our development team. It would also explain why the doubling time for many of the growth parameters we see is typically somewhere between one and two years. It typically takes two years to conceive, design, prototype, test, manufacture, and market a new product, and an increase by a factor of two is a more realistic goal than a factor of five or ten. The rate of growth (the curvature, or the slope of the curve) will in this case reflect the way in which the company is managed, and not something inherent to the technology itself.

But it can't be the entire picture. There are many technologies for which growth does not appear to follow an exponential curve – skyscrapers, batteries, or jet engines – and where the companies involved undoubtedly still have ambitious goals. Then there are other technologies that have followed an exponential trajectory even though it would seem that no one had consciously set that as the goal. This applies for DNA sequencing which has recently been shown to have a price per base pair half-life of 22 months.

In his book "What Technology Wants" from 2010, Kevin Kelly, founding executive editor of Wired magazine, observes that we primarily see exponential growth in those technologies where the improvements derive from scaling things down, making things smaller, packing things closer together etc. In a microcosm where the building blocks are electrons, photons, genes, bits, frequencies or pixels, exponential growth can be sustained. That's the reason why skyscrapers "grow" slowly. It's also why it's proving difficult to make batteries smaller and more efficient: they have to store as much energy as possible.

The conclusion is that in a world that is developing exponentially, we – as individuals, companies, and society – must be more proactive with respect to the future than we have been up until now. As companies, we must be careful not to invest too heavily in current technologies: as individuals, we need to become increasingly better at revising our understanding of what is possible.

Answer: It'll take 44 minutes to fill up the stadium (8,796,093 m^3 of water).

PART 2
FIVE EXPONENTIAL TECHNOLOGIES

4 COMPUTING AND COMMUNICATIONS

Computers, Network and the Social Life of a Refrigerator

Before we take a closer look at the technologies themselves, we will introduce three concepts that we will refer to throughout the following chapters: Exponential Acceleration, Creative Crossing, and Intrinsic Disruption.

Exponential Acceleration is a way to describe the rate of change we are facing. That exponential growth exists is nothing new. An annual population growth of 3% or an interest-bearing bank account with an interest rate of 1%, are both examples of exponential growth. We just don't perceive them as being exponential since the growth rate is so slow – and we have plenty of time to adapt to the changes. However, when the doubling time is just one or two years –as exemplified by Moore's law – we need to be vigilant and agile.

Creative Crossing is a way to describe the creation of a new technology, a new product, a new process or a new procedure by crossing two or more existing technologies. This convergence between and intersection of different technology trajectories is an important concept to understand to fully appreciate the implications of the subsequent developments. It is often through interaction with other technologies that new, previously unseen, and surprising possibilities emerge. Smartphones – a cross between computers, phones, cameras, and, let's not forget, wireless and network technologies – are a good example. Amazon – born at the intersection of bookstores, websites, and mail order firms – is yet another. Fortunes can be made at Creative Crossings.

Intrinsic Disruption is used to describe those situations where an established trend or development path suddenly comes to an end, and the boundary conditions change drastically. Examples of this include the collapse of planned economies, the fall of the Berlin Wall or the Arab Spring. These changes can be attributed indirectly to developments in technology and how they are creatively crossed by new minds with solutions to problems we didn't even know existed.

By way of example, what happens exactly when you cross a camera with mobile telephony and the internet?

First of all, our lives suddenly become much less private when we post digital photos on Facebook and Instagram; they become ephemeral and, thanks to Snapchat, not something we feel we need to record. In addition, this reduced privacy will be a prerequisite for finding a date on Tinder and building trust in the Sharing Economy. How could we otherwise trust a stranger whose apartment we wish to rent? The list of so-called "Unicorns" (companies valued in excess of 1 billion US dollars) owe their existence to the disruptive force intrinsic in the invention of the digital photography, the internet or the smartphone.

It becomes even more revolutionary when we "cross" digital images with other digital technologies. We can create neural networks, AI that does not require humans to program them, but which train themselves with the aid of photos. Neural networks can be used to develop self-driving vehicles, or, in the case of IBM Watson, analyze X-ray images. Facebook uses neural networks to analyze pictures taken by both drones and satellites. Today, Facebook reportedly knows more about population densities and distributions than any other organization. Digital images make it possible, for both the public and the private sector, to monitor society!

Therefore, any conversation about "Disruption" is not so much about digital versus analogue or about how we can predict and avoid a "new Kodak moment". It's about how we can imagine and create more than what was before. It's about understanding how new technologies can be crossed with each other to create new products, new markets, new customer needs and values. Values that even change who we become as humans.

Despite the fact that an Intrinsic Disruption may seem to happen quite abruptly, it is often the culmination of a longer process. Exactly the same way the fall of the Berlin Wall was. We believe it is time that we all be part of steering the direction of this process.

We have tried to make our treatment of each field of technology and the associated concepts as accessible as possible while, at the same time, forcing the acceleration. So fasten your seatbelt!

Exponential acceleration

These days, most of us are quite familiar with computer technology and networks. After 30 years of increasingly faster and cheaper computers, combined with 15 years of increasingly faster telecommunication technologies, we've become accustomed to the exponential growth that characterizes this space, and take it for granted.

It is precisely the exponential growth in computing power, i.e., our ability to perform an ever-increasing number of calculations, that is crucial here. This is also the basis of the other fields of technology that we will describe later. They've all gone digital and have consequently latched onto an exponential trajectory.

However, the exponential growth within the field of computation is not just restricted to microprocessors or integrated circuits. The amount of data that we can store on a hard disk (in bits per dollar) or the amount of data that we can transmit wirelessly (in bits per second) is also growing exponentially. In reality, computer technology comprises several technologies, each of which is growing exponentially, but with different doubling times! They include microprocessors (price per transistor cycle, MIPS), RAM (bits per dollar), and storage density on hard disks.

If, for example, we plot the number of bits per dollar in RAM as a function of time, the curve goes from one bit per dollar in 1965 to 100 million bits per dollar in 2010: exponential growth with a dou-bling time of approximately 18 months.

For many years, the exponential growth within the field of networking technologies has been even more dramatic than the corresponding growth in the yield/price ratio for microprocessors or memory chips. And its impact is no less important. This growth includes significant improvements in fiber-optics, optical switches, etc. We are moving towards a cable-free world. The curve representing bits per second per dollar for wireless data transmission as a function of time doubled every 11th month (1990-2004).

The number of computers connected to the internet and the amount of data that is transmitted via these machines is also grow- ing in the same manner: exponentially. These two technologies – computing power and data transmission bit rates – are converging naturally, and therefore mutually enhance each other's impact considerably.

What are the implications of essentially free and unlimited computing power combined with cheap broadband connectivity for products, services, and jobs? What kind of Creative Crossing could it lead us to?

Creative crossings

Creative Crossing is a way to describe the creation of a new technology, a new product, a new process or a new procedure, by crossing two or more existing or emerging technologies. Searching for a creative crossing between computing power and data transmission speed doesn't make much sense. It is precisely this convergence that is the wellspring from which the vast majority of technological developments emanate. We have therefore chosen three Information Technology (IT) examples.

CLOUD COMPUTING

The first and most obvious result of crossing computers with communications is Cloud Computing, i.e., the ability to run programs or store data on servers with internet access, located remotely from our own computer. The old software development paradigm of developing, releasing, and subsequently patching the software with updates once a year, is history now. Microsoft, in particular, was created within this old paradigm, and this is one of the reasons why they are having difficulty coping today.

Today, quite a considerable number of services are run in browsers and on web servers. Versions are launched in beta before they are completely finished. They are continuously being developed and, as a rule, based on input from users. One of the consequences of this is that software – as a product – has become considerably more fluid. Agile is the new black. There is razor-sharp focus on customer value, the business model is either a subscription-based model or revenue from secondary revenue streams, and the life expectancy of any given product is often short. Google is the poster child for this paradigm.

THE INTERNET OF A 1000 THINGS

Another predictable Creative Crossing which will radically change our world is the interconnection of all the things we surround ourselves with, also known as The Internet of Things. The idea is that when both computers and communication technologies become ubiquitous and cheap, it'll be worth our while to build them into physical objects around us. In this way, all things will be able to perform simple calculations, know where they are, and transmit and receive data. This means that they will be able to perform simple tasks autonomously, collaborate with each other, and know where they are located.

This connection between our things and software will enable new ways of using them, and our smartphone will play a key role in this process. It will function as the user interface to our things. It means that you'll look to your smartphone whenever you want to check your weight, your blood pressure, how much you've exercised, or if you want to turn up or turn down the lights in your living room. Initially, it makes most sense to connect things that pertain to people (pedometers, weighing scales, light bulbs, etc.) and things that move (such as cars and busses) to The Internet of Things but gradually, as our telecommunications infrastructure become more powerful, it will make sense to collect, collate, and share data between the vast majority of things.

This is already happening, albeit only for the nerds among us. With the aid of so-called "If this, then what" applications on our smartphones, we can switch on the light in our bedroom when the alarm clock rings.

And it's not just about small conveniences such as avoiding having to turn on the light or switch off the wireless network ourselves. The ability to match people's needs plays right into the Sharing Economy. Car sharing, where technology takes care of the complexity, and makes sure that we end up at the right place. Or collaborative consumption and deals, courtesy of your fridge, shopping in concert with your neighbors' fridges.

In this way, our smartphone is a platform that can spawn a fantastic number of new possibilities. A substantial number of us carry a smartphone that not only packs a relatively large amount of computing power and is connected to the internet; it's also full of sensors such as a GPS, motion sensors, a compass, a microphone, etc. It's this platform that's the basis for an awful lot of new services that are unreasonably difficult to compete with.

VIRTUAL OR AUGMENTED REALITY

The third Creative Crossing taking shape is the growth of virtual (VR) and augmented (AG) reality. Augmented reality can be described as enhanced reality. The more powerful communication networks and increased computing power make it possible to superimpose an information filter on reality. In this way, you can enrich the reality you're looking at with digital information.

You can already try out the first generation of products if you install the LAYAR application on your smartphone, and stroll around your local shopping area with LAYAR running. When you hold up the phone in front of a restaurant or a café, you can see their current food hygiene inspection report (and maybe even the Menu of the Day) superimposed on the phone's camera image. For shops, it would be the latest deals. In London, The Tube has developed an application that shows colored stripes superimposed on the pavement and that you can follow to the nearest tube station. Perhaps the best known application is Pokémon Go which motivated millions of people to run around with their smartphones, trying to capture the small Pokémons that popped up all over the place – in parks, on sidewalks, even in one's apartment – on one's smartphone screen.

Facebook and Google have already implemented automatic face recognition for photographs, so it's only a matter of time before they launch an application that will make it possible for you to point your smartphone's camera at someone and view whatever information Google can gather about them – perhaps as text floating above their head, along with their latest Facebook updates?

Augmented reality is itself an offshoot of virtual reality, which was predicted a very rosy future 15 years ago. The vision was that by putting on virtual reality goggles, one could experience computer-simulated worlds (such as for training or games) or explore large datasets (such as financial or medical data). The growth of virtual reality has faltered, but now the pace is picking up. Computers are now fast enough to be able to render a virtual environment without disorientating people i.e. without causing dizziness. In 2016, three players each launched their own new VR equipment: HTC and Oculus (which is owned by Facebook and Sony). Google has also entered the VR space but instead of making new hardware, Google leverages people's own smartphone screens as the portal into the virtual reality environment. The sensation of entering into the computer's domain is fascinating, and the prospects are staggering.

Try to imagine what will happen when the virtual world becomes just as convincing as the real world. Will you still continue to travel? In virtual reality, not only can you travel quickly, you can also travel through time. What will a workplace look like now? Will we still attend conferences?

Intrinsic disruption

The exciting and productive Creative Crossing will be viewed as an Intrinsic Disruption by the established companies and could force them to innovate or shut down. We have chosen three examples.

1. **HERE YOU GO - IT'S FREE**

Right now, the business models that currently underpin digital businesses are undergoing a revolution. Most products are free for the average user, and services for companies are sold as subscriptions at very competitive rates. Revenue is generated from supplemental services, advertising, and data mining. At the same time, the rate at which these companies can scale up is incredible. Google is, again, the classic example of free products and extreme scaling. How will your company survive if your competitors give away their products for free?

The rationale behind these developments can be found in the relationship between the digital product itself and the exponential growth of the performance-to-price ratio. In order to manufacture and sell traditional, physical products, one requires resources. Transportation alone restricts how large a share of the global market a single company can capture. More importantly, manpower is required to produce them. The cost of data communication, computing power, and data storage is practically zero. Once the digital product has been developed, it is for all intents and purposes irrelevant whether it is used by one or one billion people. The marginal costs are effectively zero. Perhaps you recall the French mathematician, Joseph Bertrand, and his axiom from 1883: "In a free market, the price will approach the marginal cost."

2. **EVERY HOME A HOTEL, EACH CAR A TAXI**

This relationship gives companies with digitally based business models an awful lot of room to scale up their products and generate revenue in a variety of different ways.

Airbnb and Uber are good examples of this. Airbnb is well on its way to becoming the world's largest hotel chain. The only difference is that Airbnb doesn't own a single bed; instead they broker their users' private dwellings. It's the users themselves that post and update their advertisements and interact with the guests. The cost of adding an additional bed to their website is zero for Airbnb. The cost for a traditional hotel is high; they have to build it, furnish it, and hire staff to run it. Who's going to win market share in that competition? Uber does exactly the same thing in the transportation space. And in both cases, it's the users themselves that invest by choosing to live in a slightly larger dwelling with a room with a view, or to buy an extra car, just for Uber.

3. THE SINGULARITY AND LOST ARTS

Ray Kurzweil maintains that the growth of computing power will bring us to a point where machine intelligence will surpass our own, and that we will begin to integrate with the machines before that point. In much the same way that we formerly couldn't manage without books, and then we couldn't manage without radio and TV, today we can't cope without smartphones or the internet. When Jonathon Foer, in his book "Moonwalking with Einstein", talks about why memory techniques (mnemonics) have become a lost art, he rationalizes along the same lines, that unlike Cicero, we no longer have to commit speeches to memory. We can, just like Barack Obama, use a teleprompter and use to-do lists, calendars, phonebooks, diaries, and the internet!

In the future, will it be possible to have a cache surgically implanted? Or wirelessly connect the brain to an external memory? Have Wikipedia in the cerebral cortex? We truly believe that the answer is yes. And soon. It may sound crazy, but so far we haven't had any problem integrating with technology: from spectacles and hearing aids to prostheses and pacemakers. The question is: what other faculties of the mind like mnemonics will disappear when we are continuously connected to the "Cloud"?

5 ARTIFICIAL INTELLIGENCE

The perfect worker

For hundreds of years, the ability to play chess has been universally regarded as a sign of high intelligence. Around the end of the 18th century, a chess-playing automaton under the name of the Mechanical Turk toured Europe. It was a life-sized mannequin torso, decked out in a turban and with a long beard, and was built into a desk with a chessboard. It actually played a pretty good game against its human opponents. However, the Mechanical Turk turned out to be a hoax. A chess-playing human operator was hidden inside the desk: it was he who decided and controlled the automaton's moves. An artificial artificial intelligence, you could say.

The Mechanical Turk finally became a reality in 1997 when IBM's computer, Deep Blue, beat Gary Kasparov in a chess tournament. Today, however, not many people consider Deep Blue to be truly intelligent. Kasparov used creativity and intuition. These are competences that humans i.e. human intelligence, master considerably better than any computer. The only reason Deep Blue won was because it could compensate for these shortcomings by being able to calculate faster than Kasparov. Much faster. Deep Blue could analyze an impressive 200 million positions in a minute. A remarkable consequence of the hold that computers have on the game of chess is that Grand Masters and international chess tournaments are no longer the focus of worldwide attention they once were. When Boris Spassky and Bobby Fischer vied for the title of World Champion in Iceland in 1972, it was framed as a duel between the ideologies of the Soviet Bloc and the Free World. Technology is always fascinating, and when it surpasses the abilities of humans in a particular field, the performance of humans in this field suddenly becomes boring and uninteresting.

We often distinguish between weak and strong AI. The chess computer is an example of weak AI in that it solves simple logical problems by virtue of its computing power alone. A host of solutions within this category are available today. Siri, the occasionally not-so-understanding assistant on your iPhone, is another example. In addition to speech recognition capabilities and access to the functions on your phone, Siri has access to answer engines such as Wolfram Alpha, and can answer simple questions such as how many people live in, for example, the US. Other examples of weak AI include autopilots, warehouse robots, or Wilson, IBM's Jeopardy-playing savant.

It's difficult to delineate between strong and weak AI. The closest we can come in practice to defining strong AI is still the Turing Test, proposed by Alan Turing in 1950. We consider AI to be strong if, after conducting an extended dialogue with an AI via a neutral communications channel (for example, text based communication via the internet), we are convinced that we have been communicat- ing with another person.

However, as early as 1966, a relatively simple computer program by the name of Eliza was capable of deceiving quite a lot of people. Today, it is not uncommon to come across so-called chatbots on the internet. Google "Eliza" and see for yourself how friendly and reassuring "she" is to talk with or, alternatively, try googling "Jabberwacky", which is wacky enough to make it quite interesting for you to see if you can figure out how it thinks. Chatbots that communicate with us via text are already quite widespread today: soon they will start talking to us.

Our experience with the Turing Test and chatbots would seem to indicate that what we consider to be intelligent is anything that demonstrates a versatile ability to understand ambiguous communication – and with which we can establish a rapport. What is particularly interesting is that our relationship with IT as a tool will change when we can communicate via a natural language interface with an entity that understands what we say. In this way, AI will make technology a more integral part of our lives.

When the American mathematician John McCarthy first coined the term Artificial Intelligence (AI) in 1956, he defined it as intelligent machines. Today, we view AI more as software. Even though the code is run on a microprocessor, we don't consider the microprocessor to be a machine, but rather an intermediary between us and the machine. AI is therefore probably best described as a flexible, rational agent that understands the environment in which it finds itself and acts in a manner which maximizes its chances for success.

AI is a multifaceted field with many interdependent disciplines. At the core, we have the cognitive functions such as problem formulation, analysis, and interpretation. We could also add flexibility and "fuzziness" here (call it creativity and innovation). Then there are the input-output functions such as speech synthesis and speech recognition. Finally, there are the robots' physical functions, which can in turn also be split into subcategories.

Activities within the field of AI are directed at solving problems such as establishing correlations, planning, learning, understanding languages, perception, and the ability to both move and manipulate objects. Research is performed in such diverse academic fields as computer science, mathematics, psychology, linguistics, philosophy, and neuroscience. One of the challenges has been that each of these fields has its own definition of what intelligence is. This makes it difficult for the researchers to define the goal of their research. All too often one gets the impression that the objective is to recreate human intelligence. Researchers are obviously inspired by the structure of the human brain, and one of the long-term objectives is also to recreate a general-purpose AI i.e. an intelligence that can solve many different tasks in a versatile manner. It is important to realize, however, that the AIs that are being created today cannot be compared directly to human intelligence. Not that they are less smart: they are often considerably better than humans are at the task in question. It's just a different type of intelligence.

It is amusing to note that whenever a piece of software is developed to perform a task that previously had been characterized as requiring (human) intelligence – such as driving a car or facial recognition– then suddenly we don't consider it to be intelligent. We call it a functionality, an algorithm, or maybe even machine learning, but not artificial intelligence.

AI is also inseparable from robotics. Navigation is a key aspect of AI. By that we mean the ability of the robot to move about and perform its tasks. AI can therefore have a physical embodiment in the form of a robot, or be software that runs on a computer.

Exponential acceleration

Acceleration in this field is influenced by a number of tangible factors, each of which is of an exponential nature. First and foremost is the exponential growth in computing power: this is mandatory. The name of the game here is to make hardware that is both faster, smaller, and more energy efficient. IBM's TrueNorth project is therefore of particular interest and could have a significant impact on the development of artificial intelligence. The objective of the project is to develop a chip that in many ways resembles the way the human brain is structured and which can perform complicated calculations using considerably less electrical power than traditional computer chips. TrueNorth can currently simulate 1 million digital neurons that communicate with each other via 256 electronic synapses. It can perform 46 billion synapse operations per second while consuming only 70mW of power. It is paramount that the energy requirements be drastically reduced to make it feasible to integrate AI in smaller and ubiquitous devices such as smartphones and earphones.

Second is the growth of the amount of knowledge available in an electronic format and that can be tapped into by AIs. What is interesting in the context of AI is that this data plays a dual role. On one hand, the huge amounts of data in and of themselves create a need for AI. On the other hand, the data is the training material we need to be able to train the AI effectively.

The third factor we will mention here is Open Source and the Network Effect. There are a large number of open source initiatives within the field of AI today. Both Google's TensorFlow and R, a programming language for statistical computing, are just 2 examples. These tools are available to everyone with an internet connection and are powerful enough to develop complex solutions. Put another way: you no longer need a large IT department full of software engineers to develop AI solutions.

IBM's Bluemix is probably the best example of how the barriers to developing solutions based on AI have been removed. With the aid of a user-friendly graphical user interface, you can "drag-and-drop" cognitive capabilities in the form of sentiment analysis and natural language translation modules. In other words, you no longer need to be able to code in order to use the advanced tools. It can be compared to the development of tools to create websites on the internet. Before the advent of Content Management Systems, developing a website was the domain of software engineers and coders. Today, anyone familiar with a computer can set up and publish a website on the internet. The ever-increasing availability of advanced tools for AI is following the same trajectory.

Finally, there's online education. This is also a factor that strongly contributes to strengthening the level of competency in general within the field of AI. Today, the vast majority of AI projects originate from the large tech companies. If, in the future, AI is to be ubiquitous, then more talent needs to be trained for this work. Both Udacity and Coursera, two online education platforms, offer free courses that cater to all levels.

Creative crossings

ADVANCED PATTERN RECOGNITION ON THE STOCK MARKET AND IN HEALTHCARE

The human brain is good at pattern recognition, but not, however, when the patterns occur over longer periods of time. In this situation, computers are significantly better. The methodical chess computer has consequently found its niche in a number of areas where there are large amounts of data and where variations over time are crucial.

One of these areas is the stock market, where the returns that can be earned by a successful implementation can obviously be quite considerable. In 2007, Rebellion Research launched the first AI hedge fund. The AI wasn't seeded with any particular strategies or rules, but it has itself analyzed how different factors affect stock prices. All on the basis of 20 years of data from markets from all over the world.

Today, there are considerably more AI funds on the market, just as AI decision support systems for, for example, risk management have appeared. The amount of data is growing at a fantastic rate, and it's no longer possible for any single individual to keep track of it all. That's not a problem for AI. The more data it processes, the better it gets. In addition to being able to sift through huge amounts of data, AIs have another advantage compared to their human colleagues: they don't have any emotions. Put another way, they don't get "carried away," which can often be a problem for humans and which has a negative impact on returns. Today, the majority of the investment funds managed by humans still perform better than AI funds, but for how long?

Developments within the fields of cognitive functions and speech recognition have also been significant. In January 2011, IBM presented the Watson program, which was capable of very advanced interaction with humans. Watson aced Jeopardy which, in addition to a very broad knowledge base, also requires the ability to comprehend ambiguous questions. IBM's objective was obviously not to make a game-playing computer but to communicate, quite brilliantly, to its broad customer base, that the company has a product that is capable of (via a speech recognition interface) understanding a complex field, searching databases for answers, drawing conclusions and communicating the answer verbally in an easily understood format.

IBM is now launching Watson in a number of exciting areas. One of these is health: in particular cancer diagnosis. The ambition here is to gather together all available medical research, pharmaceutical data, and a relevant group of patients' DNA, and use the Watson technology to discover previously unknown correlations. The hypothesis is that cancer is best characterized by associating it with a specific DNA mutation rather than in which part of the body it manifests itself. By fine-tuning the treatment according to the type of mutation rather than the location, the efficacy of the treatment can be increased. The ability to see correlations in such huge datasets is only possible with AI.

Watson can be used in areas other than cancer within the healthcare sector. Developments within the sector are driving increased specialization, thereby making it more and more difficult for the specialists to maintain a holistic view of the patients when diagnosing. Watson could play a significant role here as the doctor's assistant.

The ability to see patterns in huge amounts of data reached new heights when Google Alpha beat the world champion in Go in 2016. Go is a traditional strategy board game that is characterized by its complexity. After only two turns, there are almost 130,000 possible moves available to a player. Compare this to Chess where there are "only" 400 possible moves available after two turns. Consequently, Google Alpha couldn't just "calculate" its way through the game but had to make use of pattern recognition and a methodology which can best be described as human intuition. What was interesting was that Google Alpha began to make moves that no human player would. At first glance, these moves seemed to be wrong, but after closer analysis, it could be seen that they were based on a logic that wasn't obvious for human players. Google Alpha was not only capable of learning from humans, it could also see patterns and raise its game to a new level. Deep Blue could calculate; IBM Watson can calculate, see patterns, listen and speak; Google Alpha can do everything IBM Watson can but it also has, for the very first time in an AI, its own intuition.

We can envisage many more possibilities such as Watson the board member. In addition to performing regular board duties, Watson would be able to datamine the companies' IT systems and provide the board with much more insight than previously possible. IBM has developed Watson in such a way that it can easily be integrated into one's own IT solutions.

Many help desk and call center functions have been outsourced to the Far East from Europe and the US in recent years because the technical expertise required to provide the service is available there at a much lower cost. But it is not beyond the realms of possibility that the next generation of call centers will just consist of a good speech recognition program, some complicated algorithms, 4-5 Terabytes of specialized knowledge, and internet access.

And call centers are only the first of many service functions that can be "AI-sourced." Throughout the entire 20th century, the Industrial Society's work functions have been increasingly automated, and this trend will accelerate more when computers and robots are intelligent enough to perform the Knowledge Society's core functions. At Oxford University, the Oxford Martin Programme on the Impacts of Future Technology found that up to 50% of tasks currently performed by people are likely to be automated during the course of the next 20 years. Some of the jobs that will be impacted the most include: drivers, shop assistants, office personnel, machine operators, security guards and accountants.

These perfect workers don't need to sleep and don't go on vacation, and, given the right learning algorithms, they can take of their continuing education themselves.

How long will it be before AI supplants all white-collar workers, either partially or completely? What kind of education would you recommend to your children?

AI AND ROBOTS

Robots and AI are joined at the hip: the ability to move about freely requires intelligence. This becomes clear if we look at Nature, where things that are fixed – such as grass, trees, and bushes – don't have a brain, whereas things that can move about – such as mice and birds – do. The brain's original function is best described as a navigation system. We got it so we could move about without hurting ourselves.

That's why robots are also so dependent on AI. The best example of this is the self-driving car. The car itself is just like those we are familiar with today, and the sensor technologies that are used to gather information about what's happening in the vicinity of the car aren't particularly new. What makes the self-driving car possible is the computing power in the computer that processes the input from all the sensors. Google started this development, and they are still ahead, but now all car manufacturers are investing heavily in technologies that can make their cars autonomous. The first prototypes of self-driving cars have already been developed and are being tested in numerous countries. The biggest obstacle to self-driving cars is no longer technology, it is legislation.

Self-driving cars are an interesting development that will have many implications. For example, how will the real estate market react when transport time is now "time for work" or "time to sleep"? What about ownership of cars? When the car can come to me, then it might just as well be one that matches my current transport needs (long trip, short trip, with or without luggage?). This opens up whole new business opportunities: who will be the Spotify for cars?

Take drones, small unmanned aircraft that could easily be employed for more peaceful purposes than is the case today. Examples include transportation and search & rescue operations in inaccessible regions.

Intelligent robots are also making inroads into healthcare: robots to help the physically handicapped to eat and caregiving robots for dementia patients. Or what about the world-famous physicist Stephen Hawking, who had increasingly sophisticated gadgets developed which made it possible for him to communicate with people around him despite the fact that he was almost totally paralyzed by Lou Gehrig's disease.

Robots are beginning to encroach on types of work that we would have insisted – at least several years ago – required a human touch to handle. It's said that pornography was a major contributing factor to the growth of the VCR (Video Cassette Recorder) and later the internet.

Will sex androids be robotics' big breakthrough?

Intrinsic disruption

From Rabbi Loew, who created a living Golem out of clay in the streets of Prague, to Goethe's Faust and Frankenstein's Monster, to HAL in "2001: A Space Odyssey." On the one hand, we dream of a utopia, where intelligent and helpful robots cater to our every whim. On the other hand, we fear that this technology can be abused or, even worse, that the technology itself becomes "self-aware" and decides to control us instead of serving us.

It is inadvisable, even dangerous, to compare computer intelligence to human intelligence. We need to do away with the idea that AI and robots are more stupid than humans and can only perform tasks that we don't want to do ourselves. The objective of AI is not necessarily to create a copy of human intelligence. Today, AI is already far superior to the human brain in a number of areas. And as we look towards the future, the number of areas will increase. In other areas, AI is way behind. They are two different types of intelligence, and it rarely makes sense to compare them to each other. Our ability to navigate in this field going forward is strongly dependent on our ability to truly understand this difference and thereby only bring AI into play in those contexts where it makes sense. We will be witness to AIs that have nothing in common with human intelligence. Small, specialized programs that only do one thing but do it extremely well i.e. drive a car or translate from one natural language to another. Or, as Kevin Kelly writes in his book "The Inevitable", we really don't want the AIs to become conscious.

Nonconscious intelligence is a feature. We want the self-driving car to only concentrate on driving and not be frustrated over an altercation with the garage door opener.

From the fields of robotics and computer animation we have the term "The Uncanny Valley." This refers to the sense of revulsion that people experience when human-like imitations (robots, for example) look and act as if they are human, but aren't.

As robots and computers become more and more lifelike, we will slowly but surely begin to regard them as something other than machines or software. When we saw photographs of the Earth from space for the first time in the middle of the 1960's, we saw a bright, isolated and unprotected planet. A lot of people experienced a disconnect then because this was at variance with their established view of Earth as their home and the basis for our existence. Just like the feeling you get when you orbit the Earth in Google Earth.

In the film “Her”, Theodore Twombly falls in love with his computer’s operating system. What kind of Intrinsic Disruption do you think you would experience if, at some point in the future, you look into an android’s eyes, listen to its voice, and suddenly feel your heart skip a beat?

6 3D PRINTING

Why matter matters! by Märtha Rehnberg

Before you venture into the world of 3D printing, take a moment to observe 'stuff' in the room you are in. Look at the lamp that lights the pages of this book (or the electronic device you use to read). Reach out for the glass of water next to you, your pencil or perhaps the shoes resting next to your chair. Also, consider the surface of this chair; its material, shape and size. Are you comfortable? Are you sitting just right?

Its designer would like to think that you are. Like most designers, she or he has designed this chair with you at the center. Your needs, your body and your taste. Did the designer get it right? Or come to think of it, would you have sat in a slightly different chair – if only you knew how to design and produce?

Herein lies the promise of 3D printing: that one day, the material, shape and size that currently make up our material world, is no longer defined by a few but by all of us.

Just press print.

3D printing is a digital production technology that deposits any given material, additively, to create a three-dimensional object. It does not subtract from a large chunk of raw material to achieve a final desired shape, like machining would. Nor does it need a mold in which to pour raw material, like casting would. 3D printing builds objects much like nature: one layer at a time, without waste. It takes instructions from a digital file of the object and is agnostic to what it produces. You decide. Complex geometries, honeycombs and lattice structures – the additive and digital nature of 3D printing makes complexity affordable, and designs that would be unimaginable with traditional technologies possible.

If you can dream it, you can print it.

Since alterations to your 3D print cost no more than the minutes needed to re-sketch it in your software, there is no need to manufacture a large batch of one product to yield positive returns on your investment. No need for deep pockets to partake in this sort of manufacturing. You will print your shoes, pencil or glass – all in one print!

The transition from economies of scale over to economies of scope, means we go from manufacturing standardized products en mass, to customized products for the individual. "I'm sorry, we don't have this shoe in your size" is an obsolete term in a 3D printed reality that should now compensate not only for the length of your foot, but also its width. Even the unique way in which you walk and run.

And the plot thickens. Take another look at the 'stuff' in your room. On average, 90% of it is shipped to you across national borders. When we start producing after demand rather than before, by being close to the end customers and able to respond to their needs fast, we will certainly beat the cost savings achieved by offshoring. In select industries, we are looking at a new era of production where decentralization enabled by digital technology will undermine centralized export processing zones and low-cost labor in developing economies.

And of what becomes the manufacturing industry when we can all access it, from home, as consumers and producers, at the click of a button?

Exponential acceleration

The dream of "prosumerism", when the consumer is the producer, was envisioned by futurists back in the 1980s. Alvin Toffler was one of the first to coin the term in his book The Third Wave. But even Gene Roddenberry picked up on a similar future scenario in his Star Trek series that pioneered during the same decade. The machine was called "the Replicator" and would produce any object its user desired. So, it may not be surprising that the media heralded 3D printers as "revolutionary" when the first ones appeared during the exact same time. The timing seemed perfect, but the technology was far from it. It would take another 30 years before the media picked up on the technology again. And rightly so.

By this time computing was good enough to make 3D printing fast, precise and cheap and the internet adoption high enough to make designs accessible, shareable and hackable. Most of the early patents had expired, fueling innovation in the Maker movement and increasing competition in the consumer market. Where the first plastic 3D printers of 1986 cost 200,000 dollars, they now cost less than 2,000 dollars.

Now, we can finally print in metal alloys which is interesting for heavy industries: stainless steel, gold, silver, titanium, copper, aluminum and many more. We can print carbon fiber infused plastics that are stronger than metal, or even print in graphene sheets – the strongest of them all. We can print ceramics, glass, solar ink and organic materials. A pizza 3D printed in 78 seconds. Cell scaffolds into which we integrate your cells to artificially construct you a new organ.

Clearly, the technological advances needed to produce a 3D printed heart are much greater than to produce a 3D printed plastic cup; not to mention the price tag on metal versus plastic 3D printing. But if we believe in the exponential curve, it may be a worthwhile investment today, to start playing with what's already out there. The first step to becoming a prosumer may be smaller than you think.

And you don't even have to buy a printer. Here's a dare:

> Download a digital file of an object you want to 3D print (for free, on a platform like thingiverse.com or grabcad.com). Now send your file, called "STL" (the pdf's of 3D printers) out to your local network of makers (those with 3D printers at home). You find them on the Airbnb of 3D printing – our personal favorite is 3DHubs.com (we have no stake in any of these companies!). Within 24 hours you will get a quotation including price, color, and lead time. Average lead time? 48hours! Better yet, choose a maker close to you – and invite yourself in to see your object printed over a cup of coffee. In Copenhagen for example, there are more than 1,000 3D printing hubs connected to this platform. Take your pick.

Creative crossings

You will soon find out in step 1 of our dare, that there is a universe of digital files of printable objects. And it's expanding by the day. We can turn all the 'stuff' around us into digital files, so therefore we do. But that doesn't mean we will all start 3D printing and do it from home. We like to say that 3D printing today is where the digital camera was without the smartphone: uninteresting as long as our consumption patterns stay intact. What we need is the Instagram of 3D printing; the creative crossing that transforms our relationship to 'stuff'.

Location, location, location

When NASA announced they had 3D printed a plastic wrench in orbit, they were met with suspicion by tool lovers. How could a plastic wrench compete with the real thing? It turns out that in orbit tools literally get lost in space. To circumvent the hefty 10,000 dollars needed for every pound of payload sent into orbit, and half a year of waiting for new hardware to arrive, NASA sends a digital file to a 3D printer in space.

So, the "Replicator" is already here. And, why confine it to the boundaries of the spacecraft? Today, we have learned to 3D print with pulverized meteorites, "alien 3D printing", that will allow us to use local materials when we eventually need habitats on places like Mars. Better yet, why not print exponentially self-replicating bacteria that can build for us? At Delft University in the Netherlands, biologist Dr. Anne Meyer 3D prints bacteria that erect structures from moon dust!

In this creative crossing, it's all about the geographies and situations in which 3D printing is "good enough" and can be coupled with decentralized energy.

And these situations exist back on earth too. They can be extreme cases like supplying parts for a vehicle damaged in a war zone. Or getting access to medical equipment after a natural disaster. The 3D printed plastic wrench can also be useful to the many villages around the world located a day's walk from the nearest town. A less extreme but more common scenario.

Where there is a 3D printer there is access.

For your feet only

In 2016, adidas 3D printed some thousand shoes as an experiment. One year later they rolled out their first "Speed Factory", spitting out 100,000 shoes that year, and half a million the next. The numbers seem ridiculous for a company that currently makes 300 million shoes per year, but not many doublings are needed to fully converge the industry. Take a guess, and find the answer at the end of this chapter.

Adidas' decentralized factories use 3D printing to reduce the lead time of shoes-to-shelves from 3 months to days. But speed alone isn't enough to make us pay the extra buck. Instead, the company sees a future where the retail store becomes the factory and 3D printing is crossed with 3D scanning. You walk in, get your foot 3D scanned, and the shoe printed hours later. Perfectly designed for your feet only. Et voilà – a premium product for an eager customer.

The product awakens

Another fascinating creative crossing we see, is in using AI to design for 3D printing. "Generative Design" is an upcoming field where the designer defines some product attributes such as durability or size, but then an AI takes over and generates the final optimal design.

Topology optimization with algorithms is nothing new, but applied to 3D printing the designer will not include a restriction on complex geometries as complexity comes free of charge. And the designer can ask for new, previously luxurious, materials as the additive nature of 3D printing means you only pay for each layer you add (in contrast to losing money for every piece you subtract!).

Try searching for "3D prints designed by AI" and you will find bizarre, alien-looking objects unlike anything you've seen before! But also, beautiful structures for construction and organic creations appealing to the inquisitive eye. Often, the AI-designers aspire to the laws of nature, as Nature knows best through millennia of experience how to resourcefully shape the world through additive production. And so, maybe it's okay to get a little help to disrupt the assumptions inherited from the old, industrial paradigm of production?

In the end, we get to choose.

Intrinsic disruption

One of the most famous prosumers of the 3D printing era, has to be Cody Wilson. Back in 2013, Cody 3D printed "the Liberator" – a workable gun. If you had a plastic 3D printer, a nail and a bullet, the Liberator could be yours just one download away. To the authorities who finally claimed the file 3 days and 100,000 downloads later, the provocateur claimed that he was making use of the first amendment of the US constitution: his right to speak. After all, the file was just a piece of information, not an actual gun. Or what was it?

For when does the product become a product in the era of digital production? And who is Cody? A citizen exerting his freedom of speech? Or is he an arms' dealer?

5 years later, the US authorities have yet to figure this one out. Meanwhile, in Australia the digital product has been defined. By law, if you store a digital file of a gun on your hardware, you own a gun!

But there is more to learn from Cody than the dilemma he represents to our governance systems. To the second amendment gun proponents like the NRA, the Liberator was laughable: it could only fire three bullets before the plastic had melted beyond repair. But what if it was good enough for that one killing blow?

What Cody was able to do, was to question what defines a gun. For him, it wasn't about printing a gun. It was about printing something, anything, that could fulfill the same function.

This is where many of us, raised in a different era, will fail to see the opportunities of 3D printing. We will look at 'stuff' around us, thinking about how to replicate it with 3D printing. And in most cases, it won't make sense! Until we understand that the old products and the new are competing on different terms, they are de facto incomparable.

In this paradigm, the product acts like software. Just like the reminder on your smartphone when upgrading is recommended, you get a newsletter from your favorite designer who has upgraded a design: "throw the old part back into the shredder and print the latest version!".

The product development cycle turns into a spiral, aimed at continuous improvements for the individual's unique needs, preferably by the individual herself, with grander needs in mind than what Cody had. Hopefully, by the individual that starts pondering whether the squares, straight lines and cement around her are affecting her thoughts? Maybe it would be easier for her to "think outside the box" if she didn't live in one?

Disruptors of our material world, if you are one of them, here's a final tip: "don't design us a chair, design us something we can sit in".

And then, give it a new name.

Answer: 2019: 1B; 2020: 2B; 2021: 4B; 2022: 8B; 2023:16B; 2024: 32B; 2025: 64B; 2026: 128B; 2027: 256B. It can go much quicker though. In fact, the entire hearing aid industry in the US, fully converged to 3D printing in less than 500 days!

7 BIOTECHNOLOGY

A new Healthcare System and Eternal Life

Biotechnology is the Next Big Thing being driven by digitization. Developments in this field will change the way we perceive both ourselves and the world around us. Until now, health and medical research has, in many regards, been relatively haphazard. True, we have managed to discover many new and useful treatments, but they have also had side effects. We started by using certain plants and minerals that Nature provided us and then moved on to clinical research. Everyone is probably familiar with the story of Viagra, which was based on an unexpected side effect of a new cardiovascular drug. Now it looks as if we can design the biology exactly the way we want it.

We have always strived to understand what life is by, among other things, trying to find progressively smaller building blocks. The discovery of DNA by Friedrich Miescher in 1871 and the description of the structure of DNA and its function in cells by James Watson and Francis Crick in 1953 were pivotal. With the advent of bioinformatics, these biological processes have "gone digital." And now we can also begin to synthesize DNA: CRISPR/Cas9 technology enables us to "cut-and-paste" modifications directly in our genome at a cost that has fallen by over 3 orders of magnitude during the last few years. The race for the ultimate personalization of everything from food to medicine has begun.

However, something interesting is happening in the sector in parallel with these epic discoveries. Something that is, in many respects, comparable to what we saw happen in the IT sector during 1980's. Many young, creative types are turning their backs on the large corporations in order to start their own companies in their garage, just like Steve Jobs and Bill Gates did. There is a burgeoning "Do It Yourself" (DIY) movement growing rapidly along with open workspaces such as BioCurious, a hackerspace for everyone who wants to play with biology and perform experiments on their own body. This is an example of how technology democratizes access to what was previously a very specialized and not particularly widespread technology.

We can consequently expect to see many exciting applications in the years to come.

Exponential acceleration

Biotechnology is a combination of biology and technology. The bi- ological part is that we use living organisms to make products such as yoghurt, cheese, beer, washing powder, and penicillin. The technological part relates to how we optimize the production processes.

A deep understanding of biotechnology requires an understanding of the biology of the smallest of organisms, such as bacteria and viruses (microbiology); an understanding of their chemical processes (biochemistry); and an understanding of the individual components, such as proteins and carbohydrates (molecular biology). But it also requires an understanding of how to fit the processes together, i.e., process technology.

Mankind has made use of biotechnology for many thousands of years – to produce wine and cheese – and has increasingly industrialized production processes in, for example, breweries. The potential for biotechnology is unlimited in areas such as therapeutics, food production, etc. The field is so extensive that it's almost impossible to summarize it; from the production of washing powder to designing humans. Biotechnology is becoming increasingly more digitized; processes that formerly were physical processes are now also going digital.

The exponential curve manifests itself in two ways: bioinformatics and parallel processing.

Because of bioinformatics, we can analyze significantly greater amounts of data: we can see patterns, draw conclusions, and propose designs. And since it's an information science, bioinformatics is, by definition, already on an exponential trajectory, driven forward by Moore's Law.

We realize parallel biological processing by putting a fully functional laboratory onto a single chip that only measures a couple of square millimeters in area and that requires incredibly small fluid volumes to perform assays. In this way, it's possible to perform huge numbers of laboratory assays in parallel and thereby get our research results that much faster.

Because of this transition from analysis procedures that require physical handling at intermediate steps to chip-based processes, the growth in biotechnology will follow the same type of exponential path as those for computer and data communication network technologies. The time required to complete research projects will fall dramatically and some of the ideas will give birth to new, unexpected products. Try to google "lung on a chip", a three-dimensional chip which is expected to supplant animal testing when testing for allergic reactions, among other things.

Finally, research results and discoveries can be spread more quickly between researchers and laypeople because of IT and the Internet. DIY movements like BioCurious in particular are driven by these possibilities and create an ever-increasing amount of data based on experiments that no regulatory body would ever have permitted a biotech company to perform. In the following section, we will take a closer look at two areas where this acceleration is particularly visible: genetics and neuroscience.

GENETICS

In 1953, when James Watson and Francis Crick first discovered the chemical structure of the DNA molecule, no one could envisage the consequences it would have. 10 years would pass before it finally became clear, that the language of the genes, with very few exceptions, is universal. In other words, all life can be described using the same alphabet. We are neither chemistry nor molecules: we are information.

As if that wasn't enough, in 1973, biologists Stanley Coen, Herbert Boyer, and Paul Berg showed that information can be transferred from one organism to another by using enzymes to cut out and splice in selected sections of DNA. Now it was possible to transfer genes for desirable traits from one organism to another.

Today, we can both describe and compare all kinds of different life forms: viruses, bacteria, fungi, plants, and animals. However, the goal is not just to describe, but also to accelerate our understanding of diseases and disorders. The largest of these projects was The Human Genome Project, which evolutionary biologist and debater Richard Dawkins christened the "Son of Moore's Law" because the exponential growth of DNA sequencing could be attributed directly to Moore's Law for digital media.

When the project was initiated in 1990, many critics were quick to point out that it would take 100 years to map all the genes in the human genome given the speed at which sequencing could be performed at that time. At first glance, it seemed they had a point: after the first six years, less than 1 percent of the genome had been mapped. Despite this, the (projected) 15 year project was completed two years ahead of schedule for the sole reason that the speed at which the sequencing could be performed grew exponentially. This growth has continued after the completion of the project. The total cost for the Human Genome Project was approximately 2.7 billion dollars: today it is possible to sequence an entire human genome in less than two hours for approximately 1,000 dollars and Illumina has announced that they expect the price to fall to approximately 100 dollars within the next 3 to 10 years. (Question: did this thought just strike you?…"OK, so that means that at some point in time it will only cost 10 cents… You know, this means it will cost next to nothing to let the toilet test for cancer cells after each visit!" If you answered yes, then you truly have understood this book's message: you have taken your first step along the path – the exponential path).

Now that the human genome has been sequenced, research is focusing on understanding the differences between humans in terms of variations in our genomes. The method is quite simple. We investigate the genomes from a group of people who all have the same illness and compare them with the genomes from a healthy control group. We look for the so-called SNPs, which are both large and small mutations in the DNA. Those who have the same mutation as the patient group consequently have an increased probability of developing the illness in question.

Both Anders and Jannick have had sections of their respective genomes mapped by 23andMe, who now keeps us continually updated on all new discoveries pertaining to the specific variations in our genetic material. Here, we can track the genetically determined probability that we will develop a number of different illnesses, and how our genetic makeup affects how we will respond to different pharmaceuticals. Companies such as StationX Inc. have taken it a step further and offer tumor-DNA mapping services to cancer patients, so that the patients can choose the treatment that is optimal for them.

There are two major drivers in biotechnology today. First of all, it has gone digital: collecting the data and testing the pharmaceuticals can all be taken care of by a computer. Secondly, the price of the equipment used is falling dramatically: what was cutting edge science a couple of years ago is already productized and available for purchase today.

There are several examples of this. One example is Modern Meadow from Singularity University who employs techniques from tissue and stem cell engineering to make leather. The exact procedure can be boiled down to: "We design, grow, and assemble collagen". "Slaughter-free" meat will be here soon too. That may sound strange at first, but if potentially nine billion people choose to consume as much meat as we currently do in the developed countries, then this will be mandatory. Book your table at "Bistro In Vitro" in Amsterdam now; they may soon be serving artificial burgers with meat from researcher Mark Posts' new company, Mosa Meat. In 2013, Mark Posts first burger cost 250,000 Euros to produce: today it costs around 10 Euros.

Another example is Evolutionary Solutions who uses electromagnetic fields to control the proteins that synthesize DNA. Their technique reduces both errors and production costs substantially. Another company in this space is Cambrian Genomics; they "laser print" DNA. Just design the DNA sequence you want synthesized on your computer, and then have it delivered to your door. CRISPR/ Cas9 technology has in recent years revolutionized the entire DNA design process and reduced the cost by 3 orders of magnitude.

Finally, on a lighter note, the Canadian fruit producer, Okanagan Specialty Fruits, has discovered a way to suppress the gene that causes apples to turn brown when they come into contact with air.

NEUROSCIENCE

A completely different area is the study of the human brain. Neuroscience is a new, interdisciplinary field that concerns itself with the study of the nervous system, in particular the functioning of the brain. Combining biology, measurement techniques, and psychology in an interdisciplinary field has accelerated things.

Increasingly sophisticated scanners make it possible to see how the brain processes sensations, how and where thoughts manifest themselves, and identify behavioral markers with greater precision. It gives real hope that it will be possible to seriously address illnesses such as Alzheimer's disease and Parkinson's disease, as well as obtain a deeper understanding of disorders such as autism and schizophrenia. But it also brings us so much closer to a better understanding of ourselves as humans, to why we react the way we do, and how our phenomenal brain does its job. These are insights that feed directly into the next generation of artificial intelligences.

Creative crossings

As described in the previous section, biology has gone digital. The laboratory is now a computer. This has resulted in a substantial decrease in development times for new projects. It has long been said of internet companies, that development times for new projects there are measured in months compared to years in other industries. One of the consequences of exponential growth within biotechnology could well be development times measured in weeks or days!

CONVERGING INFORMATION AND SENSOR TECHNOLOGIES

The healthcare sector faces a paradigm shift on a number of fronts. When our knowledge of biology, genetics, and healthcare converges with sensor networks, wireless data transmission technologies, and artificial intelligence and its ability to analyze extremely large datasets, completely new and self-initiated ways of monitoring and diagnosing ourselves as well as sharing our experiences with others become possible.

We are transitioning from a passive to a proactive understanding of our health and well-being. From treating illnesses first when they occur to preventing illnesses. A number of companies make it possible for us to explore our genetic profile and perform health studies with similarly inclined people. We're talking about Quantified Self and personalized studies. Business opportunities of comparable magnitude to those of Google and Facebook will emerge because who doesn't want to do something about their health?

Intrinsic disruption

The accelerating number of opportunities for developing and testing are a growing threat for Big Pharma. What happens when we can test the different treatments for various illnesses ourselves? Many cures consist primarily of changing one's behavior, i.e. getting enough sleep, exercise and daylight, and not patented products such as vitamins. How many of the large pharmaceutical compa- nies will survive this Intrinsic Disruption?

DIY MEDICINE AND DIY TREATMENTS

Social media platforms on the internet have made it easy for us to find others who share the same interests as ourselves. Websites such as "patients like me" make it easy for people with illnesses to meet others in the same situation as themselves, share their experiences, and compare treatments. Now that it's possible to share information about one's genetic material, these sites could well become a serious alternative to the research that is currently performed within the healthcare sector. Perhaps we will see medical doctors and researchers selling their services as project managers for these groups of thousands of people who want to test treatments on themselves without waiting for FDA approval! There are a number of Intrinsic Disruptions that are interesting to look at in this field. The entire "Do It Yourself" (DIY) trend is a reaction against the power of experts, institutionalized research, and the time it takes to develop new cures and treatments within the field. The predominant discontinuity, however, is the change in our life spans.

DRAMATICALLY EXTENDED LIFESPANS

There is no objective way to determine a body's age. It would seem that our bodies don't have anything analogous to tree-rings or anything that would facilitate a "Carbon-14 dating"-like measurement of our age. However, some do point to telomere length as an indicator of biological aging: the longer our telomeres, the longer we have to live. Apparently the length of our telomeres are affected by stress, meditation, and how healthy – or unhealthy – our lifestyle is, among other things. So we are as young as we can make ourselves be.

The average life expectancy has increased by more than three months per year during the past 150 years. This can be attributed primarily to significant advances in the reduction of infant mortality rates, disease control in general, and the widespread automation of debilitating physical labor. Today, we are at the cusp of simultaneous breakthroughs in a number of areas which, collectively, can extend our life spans appreciably. Not just because we are finding cures for illnesses that are some of the leading causes of death, but also because we can slow down the body's aging process.

One of the most controversial researchers in this field is Aubrey de Grey from the SENS Foundation. He professes that aging is an illness, and accuses it of being the leading cause of death. Through his research, he has identified seven causes of aging and death, and is active in gathering and financing research into these topics.

Aubrey de Grey, Ray Kurzweil, and other life extension researchers talk about a crossover point they call the "Longevity Escape Velocity." This is the point at which the expected life expectancy increases by more than one year per year. At this point, your expected time of death will move further and further into the future! An accelerating growth that could potentially result in life spans that are 2.5 or 25 times longer than is the case today!

"I'm not sure if I want to be that old" is the usual reaction we are met with when we share these thoughts. But the comparison shouldn't be made based on our current conception of an old age, epitomized by weakness and illness. It's the healthy and active life that's extended. Picture your 250th birthday as a dance party!

The implications of life spans of this order are difficult to imagine. Even today, we see that many people choose not to retire and continue working right into their 70's and 80's. Given the prospect of a significantly longer life, will we then choose multiple careers, multiple educations, and multiple marriages?

8 NANOTECHNOLOGY

The World's Smallest Construction Site

Nanotechnology is Lego for adults, except we're playing with the world's smallest Lego bricks: atoms and molecules. One nanometer is equal to one billionth of a meter, yet we can only see objects larger than 20,000 nanometers with the naked eye. Ergo, we're "building blind."

We're also way below the scale of life. The smallest living organism we know of is 200 nanometers long. With nanotechnology, we can make things that vary in size from 0.1 to 100 nanometers. An entire Legoland beyond the range of our senses.

Nanotechnology's possibilities have already enthralled researchers, investors, and customers. However, true nanotech products are still few and far between, and the technology is still best characterized as immature. It is somewhat reminiscent of the internet bubble in 2001. But the technology continues to develop, even if some people lose money along the way. Ultimately, nanotechnology will enable us to design and build our own bodies, brains, and the world we will integrate with, atom by atom. The coming revolution, at least, is clearly discernable.

In 1957, the physicist Richard P. Feynman gave birth to the idea of the world's smallest construction site (in a talk entitled: "There's Plenty of Room at the Bottom") but the word "nano-technology" was first used in 1974, by Japanese scientist Norio Taniguchi. However, K. Eric Drexler, an American molecular engineer, is probably the best known proponent in this field. In 1986, he published his book "Engines of Creation: The Coming Era of Nanotechnology" in which he describes how one can build molecular machines that can both copy themselves and build other objects.

The invention of the Scanning Tunnel Microscope, which enabled us to "see" nanostructures, was instrumental in accelerating developments in nanotechnology in the 1980's and 1990's. After 2000, the European Union and governments from all over the world started to invest in research programs within the field, and the first commercial applications of nanotechnology started to appear.

Exponential acceleration

Nanotechnology is, nonetheless, still at the start of the exponential curve, and it's not about to accelerate wildly any time soon. However, nanotechnology's possibilities and the projects currently in the lab are nothing short of fantastic. Our ability to produce at smaller and smaller sizes is growing exponentially by a factor of four per decade. If we can maintain this pace, the size of the majority of mechanical and electronic components will become nanoscale (less than 100 nanometers) during the 2020's.

One example of our ability to manufacture at smaller sizes is MEMS. MEMS are Micro-Electronic-Mechanical Systems. The word is used indiscriminately for both the product category and the technology. They contain components that are of the order of 1—100 micrometers in size (one micrometer is equal to one millionth of a meter), i.e., 1,000 times larger than a nanometer. There are two main categories of MEMS: sensors, that measure some parameter in the environment; and actuators, that move in a well-defined manner. A MEMS is produced in a manner similar to that employed for microelectronics, i.e., thin layers of material are deposited on a substrate, which is subsequently etched until one has a three-dimensional structure with mechanical and electrical properties. The electronic parts handle the data and the mechanical parts perform the tasks.

The end result is a complete system on a chip. Integrated circuits supply the "brains" while MEMS take care of measurement and control. MST (Micro System Technology, as it is known in Europe) is already in widespread use in a variety of products such as airbags (where MEMS are responsible for detecting collisions and deploying the airbags), inkjet printers (where the MEMS chips precisely regulate the nozzles that deliver the ink), and video projectors (where MEMS control the small mirrors that adjust pixel brightness).

MASS PRODUCTION

It's one thing to build "top-down," i.e., build at progressively smaller sizes: building "bottom-up" is something else entirely. A good portion of nanotechnology research is focused on building relatively large objects atom-by-atom, molecule-by-molecule. The challenge here is to create a means of production that is big enough to make objects than can be handled by people. In other words, the machine needs to be capable of reproducing itself. However, we don't necessarily need to be capable of building something human-sized before things start getting interesting. Building nanorobots that can perform tasks inside the human body is another exciting area of research.

But there are other perspectives as well. When the scale of the structures that are being built are on the order of a nanometer in size, the structures can directly affect and interact with their surroundings on a molecule-by-molecule basis. This means that it's possible to fine-tune and tailor metal surfaces so that they can catalyze a given chemical reaction as optimally as possible. We can imagine all kinds of applications spanning from fuel cells (for generating electricity from hydrogen and oxygen) to self-cleaning clothing and extremely strong materials constructed with carbon nanotubes.

The next step for nanotechnology is biology. Completely new enzymes (biological catalysts) can now be designed from scratch. In this case, both the sequence of base pairs and how the proteins fold about themselves, i.e., the morphology, are important. Small, nanosized air bubbles are already being used, on an experimental basis, to aerate polluted lakes in China.

Nanoscale electronics can exploit electron quantum effects in completely new ways, resulting in semiconductor chips that are faster, cheaper, and with bigger memories. IBM expects to launch a carbon nanotube-based chip for the semiconductor industry's 5 nm "node" in 2019. Nanotechnology is, in many ways, the basis for the continued exponential growth in computer technology.

The wavelength of visible light is also measured in nanometers. This enables us to modify the interaction of light with matter and make, for example, "invisibility cloaks" that deflect light instead of reflecting it (this is already routinely done with microwaves).

Creative crossings

It's hard to find an area of technology where improved capabilities to build at smaller sizes doesn't automatically result in new and interesting applications. Initially, it primarily revolves around material properties and sensors, but ultimately, it's all about what uses we can find for machines when they are so small. We have selected a couple of examples where nanotechnology will have a huge impact.

MEDICINE, HEALTHCARE AND NANOTECHNOLOGY

Within the field of medicine, our ability to perform precise surgical procedures has long been recognized as the best way to avoid complications and undesirable effects. The less invasive the surgery, the lower the probability of infection, and the faster the patient will recover. This is why doctors use keyhole surgery in many situations today. In these cases, the tools are so small that the operation can be performed via a small tube. Nanotechnology will make it possible to fabricate small robots that will travel throughout the entire body via the cardiovascular and lymphatic systems and attack disease wherever they encounter it. IBM and Singapore's Institute of Bioengineering and Nanotechnology are already experimenting with this technology today. It transpires that IBM's competencies in developing polymers for ever-faster semiconductor chips can be used to "build" medication to fight multiresistant bacteria. The polymers are modified so that they attach themselves to the bacteria's membrane, cause the membrane to rupture, and release chemicals that can destroy the bacteria much more effectively. More recently, researchers have attached a protein to the nanocell so it won't be attacked by the body's own immune system.

At a certain point, we will become so proficient at building at ever smaller sizes, that we will be capable of building small robots that can transport themselves around our body and both carry out repairs and treat illnesses such as cancer. One of the nanorobots that's on the drawing board is the respirocyte, an artificial red blood cell (a nanoparticle with a store of oxygen) which can be injected into the bloodstream. These particles remain dormant until they're needed. In other words, until your heart fails or you need to exert yourself for a prolonged period of time. In these situations, the respirocytes will release a steady stream of oxygen until you can be brought to a hospital and have your heart repaired (we will meet the respirocyte again later in this book).

This is, of course, taken care of by nanorobots that are injected into the body, make their way to the heart, and carry out the necessary repairs. Unless, of course, you would prefer a brand-new, 3D-printed heart instead?

Intrinsic disruption

It's difficult to imagine what kind of world we will come to live in when the promises of nanotechnology are fulfilled. One thing is certain: the materials we will use and the surfaces that we will surround ourselves with will be completely different than those we are familiar with today.

Some of the areas where you can expect to see breakthroughs attributable to nanotechnology are the treatment of cancer, plant protection, solar energy, water purification and the early detection of illnesses. They will all lead to Intrinsic Disruptions that will make jobs, products and entire industries obsolete.

One of the biggest disruptions that nanotechnology can precipitate is a radical transformation of our understanding of the biology of humans. Nanotechnology heralds, more than anything else, the transition to transhumanism: the potential to not just make us less susceptible to illness, but also more intelligent and stronger – not to mention faster healing and maybe even with the ability to see in the dark.

Other, yet very important, aspects of nanotechnology are the extent of the consequences and the risks. If we are capable of building everything at the scale of the atom and the molecule, it will have major repercussions for a large proportion of the manufacturing industry and the work force. The current equilibrium between the work force and the economy will be displaced. However, the ultimate doomsday scenario is the risk that the Earth ends up being covered with a gray, self-replicating sludge that devours everything. Try looking up "gray goo" on Wikipedia: you will be both entertained and scared witless. Nanotechnology is no different from any other technology in this regard: it has the potential to be both a boon and a bane. Consequently, the threat of nanotoxicology and related areas should be taken very seriously.

PART 3
HOW WILL EXPONENTIAL ACCELERATION IMPACT YOU?

9 THE IMPLICATIONS

The accelerating developments in technology will have huge implications for us, not just as individuals but also for some of society's most deep-rooted institutions. In the digital age, the system's complexity is increased, and the current organizational structures are no longer adequate. In other words, we can't just incorporate these technologies into our current world with impunity. We need to fully appreciate that these technologies will have an impact on some of the most fundamental assumptions upon which our society is based.

Education

The manner in which education is organized today is essentially the same way it always has been for the past 300 years in Europe. The centralization of schools is based on the premise that both teachers and buildings are scarce commodities and that the educational system is an important element of nation-building. Globalization and the digitization of the dissemination of knowledge have altered this basic assumption. Furthermore, the acceleration of the rate of change means that the current model, whereby we educate ourselves for the first 25 years of our lives in order to work within the same area for the following 40 years, is no longer tenable. We expect huge changes within this field.

At the macroscopic level, the monopoly that the existing educational institutions have had will crumble. Change will come about in three waves. In the first wave – which is already happening – content will be democratized and the learning experience itself will be digitized. In the second phase, artificial intelligence will enable unprecedented customization of the learning experience. In the third wave, we will be able to incorporate machines into our bodies: machines that will supplement our own memory and accelerate our learning processes.

Just like other institutions, education will also gravitate towards a decentralized organizational structure. The outcome of this will be that everyone will have access to high quality material from relevant schools. We are still in the early stages of this transition, but there are already a large number of free courses available to everyone with internet access. Some of them are just video recordings of lectures; others are much more interactive with pop quizzes and feedback modules. In countries where everyone has access to free, high quality education, the effect at this point in time is minimal.

However, in regions where education is restricted to the "haves", the impact is huge. Now education is no longer hampered by inadequate access to educational resources, but instead by inadequate access to the internet.

The optimal learning process will include elements of face-to-face interaction and digital platforms. But while the virtual, digital universe is growing exponentially, the institutions' bricks and mortar learning environments are on a flat, linear trajectory. Consequently, the digital universe will gradually take over more and more of the learning process.

An exciting consequence of this transformation is that the technology is capable of simultaneously providing us knowledge when we need it, where we need it, and in a format, that is perfectly adapted to the context in question. Today we "google" whenever we need to look something up; in the near future, augmented reality will enable us to be briefed on a given topic whenever we need it. To a greater and greater extent, the learning experience will shift from being "push" based to "pull" based. In other words, we will only access the knowledge we need when we need it. In that way, we avoid the inefficiencies associated with either learning something we never need, or having forgotten something we had learned by the time we actually need it.

There are many benefits associated with traditional classroom teaching but the most effective way to learn is through mentoring with customized learning materials. Artificial intelligence will make digital teaching a unique experience for everybody. Next generation software will be able to ascertain the strengths and weakness of each individual student and, based on this, customize both the material and the exercises. We will distance ourselves from the mindset of the Industrial Revolution, where students are grouped according to their year of birth and all taught in exactly the same way.

As bandwidth grows, the impression of being physically present will be enhanced via virtual immersive environments. According to Ray Kurzweil, by the first half of the 2020's, these virtual environments will be so compelling that people will prefer them to being physically present.

The next big revolution will come when we are able to integrate non-biological memory with our brains. At that point, we will be able to download new knowledge the same way we download software today: it will be like being able to "google" with our thoughts.

QUESTIONS TO PONDER

Are you aware that it's possible to further educate yourself through MOOCs (Massive Open Online Courses) such as Coursera and Udacity?

How can you broaden the use of online education in your workplace?

Will it be through the medium of games and gaming that we will work and learn in the future? (Google "gamification.")

Do you want to change the way we learn? The XPRIZE Foundation has launched a competition to develop an app which can teach people who are illiterate to read. (Google "Global Literacy XPRIZE.")

Energy

Mankind is in a symbiosis with Nature. When we breathe, we convert oxygen to carbon dioxide. When we plant forests, we convert the carbon dioxide back to oxygen again. The extent and ramifications of our interaction with Nature is incredibly complex. We want to take care of the environment. We want to protect the Earth from ourselves, we say. But we might as well admit – like the Fisherman's Wife in the tale collected by the Brothers Grimm – that we want to reign over the Sun, the Moon, and the stars. We would rather decide ourselves and control everything around us. We would rather understand the consequences of our actions, and either change our ways or counteract them with intelligent solutions. We want to be in full control.

Energy is pivotal in the Environmental Ecosystem. Here, at the beginning of the 21st century, it would seem that our energy consumption is one of the biggest causes of harm to the environment. We are trying to compensate by reducing our energy consumption. However, population growth and increased living standards in many parts of the world make this a losing battle.

Any solution that is solely based on reducing energy consumption will not work. We need to leverage technology to find new, sustainable ways of producing energy. Increased computing power means that we can untangle increasingly complex correlations and run more and more realistic climate models to simulate the impact of different factors. In particular, the growth of sustainable energy sources such as cheap solar energy will, in the long run, provide us with almost free, CO2-neutral energy.

We have made use of the sun as a source of energy for thousands of years. Wind energy exploits the fact that the sun does not heat the Earth uniformly, and consequently creates areas of high and low pressure. Hydropower plants exploit the fact that the sun melts glaciers and snow up in the mountains. What's new is that we can efficiently convert solar energy directly to electricity – and it's getting cheaper and cheaper to do so. We're asymptotically approaching zero cost. The total amount of solar energy that is absorbed by the Earth during the course of a year is approximately 7,000 times greater than our annual energy consumption: 3.8 million EJ compared to a total energy consumption of approximately 500 EJ. Even if our consumption were to continue to increase by 20% per year (as it is does right now), it would take about 49 years to reach this level. In the medium term, solar energy is the obvious choice. In the short term, a combination of many different sources is the obvious choice. In the long term, however, we need to think out of the box.

The growth in the ratio between yield and cost for solar energy has long followed an exponential curve. And if we extrapolate this growth, we will reach a point where the cost of energy will be same as the cost of water in many parts of the world – almost free. The ratio between solar energy and cost is increasing exponentially too. According to Travis Bradford, President of the Prometheus Institute for Sustainable Development, the cost of solar energy has fallen 5-6 % each year: this implies that the energy/cost curve has grown, doubling every 15th year.

Note that the doubling time in this case is considerably longer than those of microprocessors and DNA sequencing. This is primarily because energy doesn't scale the same way that electrons and bits do. However, it is also because the cost of energy is a complex beast, affected by factors such as demand, distribution, and policy decisions to a much greater extent than the cost of computing power.

For many years it has been more expensive to produce electricity from solar energy, but now we have reached break-even. 2016 was the year subsidized solar energy became just as cheap as fossil fuel-based energy. In particularly sunny locations such as Chile and Saudi Arabia, electricity generated by solar energy is given away for free during the sunny months.

In his book "Abundance," Diamandis writes: "So when critics point out that solar currently accounts for 1 percent of our energy, that's linear thinking in an exponential world. Expanding today's 1 percent penetration at an annual growth of 30 percent puts us eighteen years away from meeting 100 percent of our energy needs with solar." Given a 5% reduction in unit cost per year, the unit cost in 18 years will be 60% less than it is today. Or as Sheick Amhed Zaki Yamani put it: "The Stone Age did not end for the lack of stone, and the Oil Age will end long before the world runs out of oil".

QUESTIONS TO PONDER

A considerable number of products are built upon the premise that energy is a scarce resource. How would essentially free and clean energy impact the markets you operate in and who will your new competitors be?

If our perception of energy were to change so that we regarded it as a technology rather than a resource, what would that mean for your products? What challenges could you address if energy were no longer a scarce resource.

Health and longevity

One of the more difficult topics to reconcile ourselves with is changes to our biology, i.e., our bodies and our life expectancy. We already use technology today where our own bodies are deficient. We transplant organs, insert pacemakers to monitor our hearts, and replace our hips and knees with artificial ones. This trend will continue as the technology develops, and consequently, the line between man and machine will become blurred in the future.

Quantified Self or "self-tracking" is only the first step in this direction. Our wish to optimize our activities – "to get more out of life"– is a strong motivator. Combining software and simple sensor data has given us unprecedented insights into our movements and our progress. The next generation of sensors will be in contact with our skin, and will not just gather information about our activities, weight, or sleep patterns, but also about our pulse, heart rhythms, perspiration levels, and body temperature. We will also be able to measure less tangible parameters such as what mood we're in, our well-being, and nourishment.

Self-tracking will make us aware of causes and effects in our lives that we simply weren't aware of before. There's no guarantee that our lives will improve because of it, but now we have the option to make the changes and track the consequences.

The next stage will be more invasive: we will insert technology into our bodies. Nanotechnology will reach the stage where it's feasible to introduce so-called nanobots into our body, initially to maintain and strengthen our biological system, but ultimately to replace it in the form of artificial organs etc.

As we mentioned in a previous chapter, one of the more interesting nanobot ideas is Rob Freitas' red blood cell: the respirocyte. Our biological red blood cells don't perform their task particularly efficiently, so Freitas has redesigned them so that they perform optimally. His calculations indicate that these red blood cells will be 100 times more effective at distributing oxygen throughout the body. In other words, anyone with these red blood cells would be able to survive for hours without oxygen. However, don't hold your breath: we're probably going to have a wait a couple of decades for Rob Freitas' red blood cells.

All these technologies will not just improve our lives within the current frame of reference. With the aid of technology, we will be able to extend our current life spans considerably. As was discussed in a previous chapter, the aging process which takes place in our body over the course of a lifetime is, in many regards, due to the accumulation of damage. During the early years of our lives, the damage is limited, but when we're around 80 years of age, the accumulated damage is so great, that we start developing age-related illnesses such as Alzheimer's. At some point, the accumulated damage will become so great that we die. Life Extension Researcher Aubrey de Grey's goal is to stop the aging process itself. His contention is that if we can stop the aging process, we can also stop age-related illnesses.

This is a very unorthodox perspective in medicine today. What Aubrey de Grey is basically saying is that we should shift our focus from curing illnesses to removing what causes them to occur in the first place. In other words, it's not about extending your life when you grow old, but more about regenerating your body when you are middle-aged. Our lives will be both longer and of better quality. While the total cost of treating illnesses may decrease, the cost of healthiness will increase.

The average life expectancy has increased by three months per year during the past 100 years or so. Both Aubrey de Grey and Ray Kurzweil are convinced that new research will enable us to increase that number to 5, 6, and 13 months per year. This growth trajectory is extremely interesting and has a slew of economic, political, and ethical ramifications.

QUESTIONS TO PONDER

Singularity University's Exponential Medicine Program showcases a cavalcade of revolutionary advances in medicine that all point towards dramatically extended life spans. If you are in good health 30 years from now, it looks like technology might give you an extra 30 years. And after these extra 30 years have passed, how many more years may you expect from exponential growth?

What are you doing today to ensure that you are still healthy 30 years from now?

Have you thought about how you are going to finance a longer life? Jannick is prepared: he has purchased a life annuity contract that first starts paying out when he reaches the age of 90.

When you need medical treatment, do you make sure that you know at least as much about your condition as the person treating you? Would deferring it by, for example, 5 or 10 years give you other treatment options because of new technologies?

Work and manufacturing

Over the course of the next 20 years, all routine manual and mental labor will become automated. Like the transitions from agrarian societies to industrialized societies to the Information Society, it will involve a radical change to the kinds of tasks we humans perform. The challenge this time round is that the transition will take place considerably faster than was the case for industrialization, and will be more comprehensive than the transition to the Information Society.

The tasks that we perform as workers will also change considerably.
Robots and artificial intelligence will take over a large proportion of our tasks. Some types of jobs will disappear completely. Taxi drivers and truck drivers that are replaced by self-driving vehicles is the classic example. The same applies to pilots, store assistants, teachers and accountants. A wide range of other types of jobs will be performed considerably more efficiently because of automation, making many of us redundant. Somewhat surprisingly, photo models are already beginning to be made redundant by ”perfect” virtual models. As discussed earlier, several research institutes have calculated that up to 50% of the tasks we perform today will be affected by automation. The big question is whether we are capable of creating enough new jobs to replace them. One thing is certain, however; it’s a lot easier to figure out which jobs are going to disappear than figure out what type of new jobs are going to replace them.

This is by no means the first time that the job market has undergone major changes; our view is that we will, as on all previous occasions, succeed in creating new jobs. Either way, upgrading the skills of the workforce is a prerequisite for making this transition successfully. This implies that the education of the least qualified members of the workforce must be a priority.

The Digital Revolution continues to sweep over us and has done so for some time now. Numerous new tools are already ubiquitous and indispensable for many of us in our daily lives. One could therefore be justified in expecting correspondingly large economic growth as a consequence of the digital economy. The thing is, it just hasn’t happened. At least not yet. The “Big 5” in this context – Apple, Google, Facebook, Amazon and Microsoft – collectively employ only 400,000 people in the US, and half of these people are employed by Amazon in relatively low-paying jobs in its warehouses. By way of comparison, this number is less than the number of employees at General Motors alone in 1979. Digital corporations can really scale up without creating that many new jobs.

And scale they do. The dynamics of the digital economy are extremely closely coupled to the network effect. The classic example of the network effect is the telephone. There’s not much utility in being the only one that owns a phone, but if everybody has one, then the utility of the exact same phone suddenly increases dramatically. This is one of the main reasons why there are 5 big digital corporations and not 500. When all your friends are on Facebook, that's where you go when you want to get in touch with them. The network on Facebook creates more value than the intrinsic quality of the Facebook product itself.

The use of these products creates data which in turn is used to create better products. In this way, a positive cycle is created and a stable market is established. This applies for the "Big 5" digital corporations as well as the challenger, Tesla. Tesla differentiates itself from the other car manufacturers in that it gathers all kinds of use case data from their cars. Data that can be used to train AI systems and build safe self-driving cars. The newly released Model 3 is expected to be 10 times safer than a conventional car.

The jury is still out on what the competitive landscape of the future will look like and how it should be regulated. Apple, Google, Facebook, Amazon, and Microsoft cannot be compared to the monopolies of yesteryear. They are not natural monopolies, they don't try to stifle competition, and they don't exploit their position to the detriment of their users. In fact, the vast majority of their users are quite satisfied with the services they provide. Despite their (monopoly) position, they are still capable of further developing their products and they invest heavily in research. But they are all based in a single country and we are all dependent on them.

It's actually a bit of a paradox. Improvements in technology and continuously falling prices create a democratization effect whereby more and more people can obtain access to resources that have previously been beyond the reach of private individuals or small companies. Small companies can suddenly be global – e.g., TED, and large corporations can do things that formerly were the purview of nation states – e.g., SpaceX.

The future of the labor market is difficult to predict but there is no doubt that the opportunities to really change things are greater than they have ever been.

QUESTIONS TO PONDER

How will your job be affected by automation?

How can your workplace position itself with respect to the "Big 5" Digital Corporations?

Are there areas of expertise in your workplace for which it would make sense to draw upon talent outside of the organization?

Do you define your job or work in terms of the product you sell or the problem you solve?

Disruptive companies

People and companies react differently to change. Some regard it as an opportunity while others consider it to be a threat. Some don't even see it coming! When we talk about change as a direct consequence of technologies that grow exponentially, the latter is often the case. We see neither the threat nor the opportunity before it's "game over."

Important as it is to understand the rate of change, it's just as important to understand where the competition is coming from. The threat of disruption doesn't come from the established players that resemble oneself. It often comes from the small startups that bring technology into play in unprecedented ways, and who understand how to exploit the exponential growth of their core technologies.

KODAK

The best example of a company that became obsolete is Kodak. There was a time when pretty much everyone in the Western Hemisphere – and elsewhere – bought Kodak film regularly. When Kodak was at its zenith in 1988, it had no fewer than 145,300 employees. Kodak was also extremely profitable, and was traded at 100 dollars per share as recently as 2000. But within the space of a decade, the share price dropped to under 25 cents, and in 2012, the company filed for Chapter 11 bankruptcy protection.

The digital photo represented something completely different to what Kodak stood for. It could in no way match the image quality requirements that Kodak's customers expected, but it could do something else. The digital photo heralded a completely different way of taking pictures. Not only could one take as many as one wanted to, one could also easily share them with friends and family. These secondary features became the decisive ones and ended up making Kodak redundant.

Note that it was not the digital camera itself that was Kodak's downfall. It was the convergence of digital cameras with high capacity hard disks (how many pictures can you take before you have to offload them?), social media (where sharing photos is what you do), and increased bandwidth (the ability to share photos both quickly and easily).

Why didn't Kodak get with the program? In fact, it was Kodak's engineers who had invented the digital camera in the first place. In 1991, they were good enough to fly with NASA. The R&D people at Kodak knew what was going on: they just underestimated how quickly it happened. Up until 2000-2003, film sales continued to increase! And the transformation was difficult too. Kodak's core competencies were photography, chemistry, and paper, and the business model was built around this. Digitization made a number of Kodak's competencies redundant and – even more importantly – it kicked the legs out from under the business model. Real change at Kodak would have required new employees and new business models. Kodak lived and died with its technology.

Kodak clearly illustrates that even though one has seen it coming, it can still be impossible to make the necessary changes. Not least of all because the transition is so rapid.

NETFLIX

Another good example is Netflix. Netflix was competing with Blockbuster for the DVD rental market. Blockbuster distributed through their stores, Netflix sent the DVDs by mail. In 2007, Netflix began to offer access to movies via the internet. The quality was nowhere near as good as the DVDs, and very few customers could connect their computers to their TVs and see the movies on a big screen. None of Blockbuster's customers expressed an interest in renting movies via the internet, so Blockbuster consequently decided to wait and see.

Bandwidth and the proliferation of smart TVs, tablet computers, smartphones and other equipment that could be connected to the internet (and could therefore be used to view Netflix) grew exponentially. By April 2011, Netflix had 50 million subscribers. Blockbuster had already gone bankrupt in 2010.

AMAZON'S E-BOOK

Amazon's sale of e-books is interesting. The story is similar to that of Kodak and Netflix in that the product, the e-book, did not initially meet the customers' basic needs. The e-book has a number of advantages that a traditional book doesn't have. In just a matter of minutes, one can access a selection of books that far exceeds that of any bookstore or library. Digital books don't have to be printed or distributed, and are therefore cheaper. While reading, one can look up a word directly from the text, share blocks of text and notes, and see how much longer it will take to finish reading the current chapter. We can also read e-books on a variety of devices (e-book readers, tablets, smartphones, etc.) and they don't take up any space. Despite all these advantages, paper books still outsell e-books.

There's something about paper that's difficult to circumvent. Studies show that we both understand and remember what we read on paper better than what we read on a screen. In other words, there's something about the physical nature of paper and books that e-books can't yet emulate.

If we apply Clayton Christensen's model for disruptive innovation to the book's specific function (to display text), paper books ought to have been retired a long time ago. Yet they haven't been. In the transition from the physical world to the virtual world, there can be linkages to the physical product that alter the picture.

Who's next?

Exponential growth can be extremely profitable for those who can both recognize and take advantage of the trajectory. But the trajectory destroys those who realize too late where it's heading. Exponential growth can either lead to fortune or to failure.

Disruptive changes will indiscriminately strike both large and small industries. For some industries, change will be obvious; for others, it will come as a surprise and be impossible to predict. Common for both is the need to be acutely aware of the transformational power that technology can wield and stay up-to-date on developments in the sector. "Only the paranoid survive," as former Intel CEO Andrew Steven Grove writes.

It's just as important to experiment by continuously introducing new concepts and products in collaboration with suppliers and customers. The experiments yield priceless insights and, quite often, a valuable network.

Many companies have experimented a lot in this regard, and many of them have also been forced to reconcile themselves to the fact that it is difficult to incorporate radical innovation that has the potential to disrupt the existing business. Organizations are designed to minimize risk, and they rarely embrace disruptive ideas. Not even the ones that originate within the organization itself.

In order to avoid this resistance to change, many companies set up innovation units outside of the organization itself. Probably the best well-known example of this is Google and GoogleX: GoogleX has incubated both successes (such as self-driving cars) and fiascos (such as Google Glass).

The rationale behind establishing these small innovation units lies in the difference between incremental innovation and radical innovation. Incremental innovation continuously improves what one already has while radical innovation creates something completely new. The acceleration of the rate at which technologies develop, and which we describe in this book, has greatly increased the need for radical innovation. This acceleration has drastically reduced the life cycle times of companies' existing technologies and products: the life cycle times are just too short now. Responsible managers know they are obliged to work openly with new technologies and new business models without letting themselves be constrained by their existing products. For this reason, the external, yet affiliated, innovation units have proved their worth.

In the next chapter, we will present our proposal for how a company can walk the tightrope between incremental and radical innovation. We will present a methodology to create innovative ideas by combining exponential technologies and we will inspire you to disrupt yourself: not out of fear but out of the desire to create more value than there was before.

QUESTIONS TO PONDER

Can you detect signs in your own company that you are “trapped in a relationship” with your current customers, suppliers, and the company’s current core competencies?

Are small startups among the pool of competitors that you monitor? And in what industries are you searching for them?

Do you keep abreast of new technologies that, perhaps when combined with your company’s existing technologies, could potentially create new business opportunities?

10 HERE'S WHAT YOU HAVE TO DO

When the rate of change accelerates as we have just described, it becomes more important than ever to be able to foresee technological developments and imagine creative crossings. It is vitally important that the innovations anticipate these technological developments and hit the right point on the exponential curve. Steve Jobs' hockey metaphor captures it very well: "…don't skate to where the puck is, but where it is going to be.". This chapter is all about how to do that.

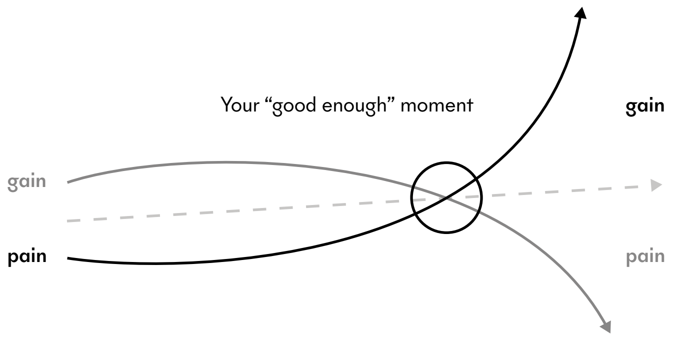
It's not that it's difficult; it's just that it takes some effort.

Balancing the past and the future

Intrinsic Disruption is particularly difficult for a company to deal with since it challenges the existing organizational value chain and the existing web of relationships between its customers, products, suppliers, all embedded in legacy technology systems. While these existing structures ensure that the company is competitive in its existing markets, it can make it blind to the possibilities of a new, disruptive technology.

All the while we continue to do what we are good at, we need to force ourselves to imagine what kinds of Intrinsic Disruptions could potentially cut the legs out from under our existing business. We need to be able to differentiate between activities that are directed towards maintaining the status quo and activities that, by virtue of the fact that they break down the existing structure, make it possible to meet new customer needs, conquer new markets, and even change values systems.

Balancing the past and the future have very different profiles as far as the amounts to be invested, the length of time required, and the returns on investment are concerned. Because of this, they both require that the organization focuses correctly in each case. As we wrote in the previous chapter, ever increasing numbers of companies are choosing to manage this challenge by establishing innovation units that can embrace the radical and disruptive forces.



Source : DareDisrupt

The figure above serves to illustrate the relationship between the two types of activities, and companies need to be able to do both simultaneously. The grey, downward sloping curve represents what we call the "sunset" strategy and is where the company leverages digitization to make the existing business more efficient. This manifests itself as "business as usual" but with short-term gains until the new Intrinsic Disruption kicks in and the old paradigm is killed off. The name of the game here is to "milk it for what it's worth".

At the same time, the company needs to find and follow what we call a "sunrise" strategy as represented by the black, upward sloping curve. This is the strategy that will ensure the company's survival and where it needs to exploit exponentially accelerating technologies. It can do so by investing in technologies that are superior yet expensive, but where the price is falling so fast that they will soon be attractive for new markets. Tesla's electric cars and DNA sequencing are both good examples.

Alternatively, it can also do so by focusing development on inferior but considerably cheaper products and then wait for the exponential improvement in quality. At some point in time, the technology will become "good enough" and consequently disrupt the more traditional products. Netflix's streaming service is a good example of this. Initially the quality was in no way comparable to that of the DVDs one could rent from Blockbuster. However, as improvements in telecommunication technologies meant that more and more people could get high-speed internet access (and thereby stream high quality video), Blockbuster couldn't keep pace.

Following this path will in all likelihood hurt in the short term, but not doing so could end up being catastrophic for the company in the long term! So, where do you start?

Exponential curve explorer™ (ECE)

Technological developments within a number of core technologies can be extrapolated relatively easily. The challenge lies in figuring out how the different technologies will converge, or bring each other into play, so that previously unknown possibilities can emerge. Our methodology is not in itself disruptive; neither does it guarantee disruptive products. However, it frames technological developments in such a way that the disruptive potential can be seen more easily. This is achieved primarily by identifying lucrative technology discontinuities.

The methodology is based on the three concepts – Exponential Acceleration, Creative Crossing and Intrinsic Disruption – that we employed when we discussed the exponential technologies. We call the model the Exponential Curve Explorer, or ECE (pronounced "easy").

STEP 1 - DECONSTRUCT

The first step in the Model is to deconstruct. Deconstruction entails analyzing the existing product (or service) with a view to identifying and listing the most important technologies that it incorporates. Even though the product (or service) itself may not be based on a given technology, the manufacturing, handling, delivery or usage of the product (or service) may be linked to a technology. These aspects should therefore also be taken into consideration.

The list of technologies is then supplemented with new technologies that one expects to be relevant for the product at some point in the future. In other words, technologies that will or could be introduced in and around the next generation of the product. It's important to focus on technologies that are on exponential trajectories: technologies such as AI, robotics, biotech, nanotech, medicine, neuroscience, energy, and IT. The "List of Emerging Technologies" on Wikipedia can also serve as a source of inspiration.

Focus on just 3 or 4 important technologies for the next steps.

> Example: If your product is telecommunications equipment, perhaps you should focus on data transmission, battery, and solar cell technologies.

STEP 2 - ACCELERATE

The second step is to accelerate. It is assumed that each technology is on an exponential trajectory so plot them each in on a 20-year exponential curve and mark off 5, 10, and 20 years. Now try to imagine what impact the technology would have on your product if the performance/price ratio increases by a factor of 30 after 5 years, by a factor of 1,000 after 10 years, and by a factor of 1,000,000 after 20 years.

At this stage, it's vital that you address the acceleration of each technology individually, and don't try to visualize them intersecting with any other technologies. We will address intersections when we reach Step 4.

After you have let your imagination run riot, you now turn to the data. You need to determine how fast each technology's performance/price ratio is really growing. We have initially assumed that the exponential rate of growth corresponds to a doubling each year, i.e., 100%. In reality, the growth rate could be either greater or lesser than this. Start by determining the curve's acceleration (or growth) for the past 10 to 20 years. If the technology has "gone digital" within the past 5 to 10 years, assume that the current growth rate will continue. If the technology has only just recently "gone digital" (or maybe hasn't even been digitized at all), then it is best to assume that the rate of growth will increase dramatically. Redraw the curve with the correct slope and recalculate the realistic performance/price ratio after 5, 10, and 20 years. This calculation will, in all likelihood, deviate from the initial estimate where it was assumed that the growth rate was 100%, i.e., a doubling each year.

> Example: Historically, the rate of technological development for each of the three technologies mentioned in the example above shows that data transmission speeds have grown extremely rapidly whereas the rate of technological development for both battery and solar cell technologies has been considerably slower (but still exponential). While past performance obviously does not guarantee future results, historical data does provide a more realistic view of what the future may hold for a given technology rather than just assuming a doubling each year.

STEP 3 - SENSE THE ABYSS

The third step is to sense the abyss. We will now try to identify what kinds of discontinuities and Intrinsic Disruptions we could potentially be subjected to.

We start by reviewing a variety of technologies. Are there any disruptive technologies on the way that are accelerating at such a rate that could essentially render us obsolete from one moment to the next? A disruptive technology can be characterized by a completely different price, performance, and/or user experience compared to the existing technology.

It's worth pointing out that digital products often follow a completely different logic compared to "traditional" products as far as pricing is concerned. The performance/price ratio for hard disks and data transmission rates are both growing exponentially. This means that the cost of storing and delivering digital products – the marginal cost – is approaching zero. When a digital product is first developed, it costs very little to scale up. This allows novel pricing strategies and even free products.

Following this, we then review trends in the market, demographics, and political factors. When we are done with all this, we ought to have an overview of the critical assumptions that need to be valid for our product to continue to be relevant. The objective being, of course, to develop our products so they are not dependent on these assumptions.

> Example: As mentioned previously in this chapter, we need to identify the "good enough moment" that is triggered by a price and/or quality disruption. Our product can also be disrupted if other players choose to make it a free feature of their own products as when Microsoft decided to provide Internet Explorer free-of-charge and totally undermined Netscape's business.

STEP 4 - INTERSECT!

The fourth step is to intersect, or "cross creatively." First of all, you try to imagine what would happen if all these technologies were to intersect with each other. What kind of new functionalities, products, processes, and methodologies emerge from these creative crossings? Next, you include additional technologies and repeat. There really is no limit to how many times you can repeat this particular step. On the contrary: inspiration from completely different fields is very important. Science fiction, in particular, can often be a useful device to get our imaginations to roam.

Note that product lifetimes become a lot shorter when the underlying technologies are growing exponentially and converge with other technologies. The products need to be updated continually, and product lifetimes of 3 to 5 years are not unusual.

Some of these products could very well lie outside our current business areas. A very important part of the process is, therefore, to evaluate the consequences for our current strategy. Would the introduction of these new products necessitate new competencies, a new organization, new partnerships, et cetera?

> Example: Creative Crossings occur especially when we cross new technologies that have become accessible because of exponential growth with the familiar technologies in our existing products. For example, it would make a lot of sense to introduce speech recognition and artificial intelligence into pretty much all existing products, systems, and processes.

STEP 5 - DREAM

The fifth and final step is to dream. This is where you bring it all together. The previous four steps should have given you a good overview of the technological landscape for your future products. So now you should try to imagine, based on this landscape, dreamlike yet undreamed-of customer needs. You should also avail yourself of megatrends such as Personalization and the Sharing Economy. Try to create a product or a service that meets a broad, generic need–or one that no one realizes that they need – and that makes the world a better place.

> Example: Solar-powered water pumps are well on the way to totally disrupting the market for diesel-powered water pumps in the poorer regions of the world.

And it doesn't have to be non-profit. One of the new value systems that has come to the fore in recent years is that of "impact" thinking which has made the traditional boundaries between profit and not-for-profit somewhat fuzzy. The upshot is that it's perfectly okay for companies to make a profit if their products have a positive impact.

Final words...
...for now

Understanding the future is not just a question of what technology can do for you, but what you can do with technology. We need to promote "technological intuition" so that we can fully understand and debate all the far-reaching implications of digital technologies. The long term benefits far outweigh the disadvantages that companies initially experience in the short term.

Any conversation about "Disruption" is not so much about digital versus analogue but more about how we can predict and avoid a "new Kodak moment". Its more about understanding how new technologies can be crossed with each other to create new products, new markets, new customer needs etc. and that thereby change what we consider to be valuable, for better or worse. The adage "Disrupt yourself before someone else does" is, in itself, only half the story. It is much better to disrupt yourself in order to create something that wasn't there before. Disruption is an opportunity to think big. We should define ourselves more in terms of what problems we can solve rather than how many products we can sell.

What can you do if the product is free? Which problems can we now solve?

We may run out of jobs in the future, but we will never run out of problems.