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GROUND RULES FOR THE 21ST CENTURY
Chapter 16

EVOLUTION CHANGES ITS MEDIUM: FROM BIOLOGY TO TECHNOLOGY AND CULTURE

In the spring of 2010 the American biotech superstar Craig Venter announced that his team of researchers had managed to build the entire DNA sequence of a bacterium from scratch and inserting it into a cell whose own DNA had been removed. Amazingly, the cell duly began to divide, and the new cells behaved exactly as their completely artificial DNA prescribed them to. This was the biological equivalent of installing a new operating system in a computer - except that the hardware in this case was *wetware*: live biological material.
We will see a lot more of this type of achievements. We are entering an era in which biology, rather than mechanics, will drive technology forward.
Some researchers use the term "living technology" to describe a class of man-made solutions, whose strength lies precisely in that they behave as if they were alive. By inserting artificial DNA in bacteria scientists should, for example, be able to program the cells to produce complex substances such as biofuels or drugs. That particular research field is called "synthetic biology" – but *living technology* is a much broader concept. It could include new materials that can heal itself if damaged, machines that can create new and improved versions of themselves, extremely intelligent and autonomous robots - or computers that fight virus by attacking the bits of code, it does not recognize, with a mechanism that in principle is exactly the same as a body's immune system.

Living technologies are found at the greatest and the smallest scale. The global Internets' billions of sensors and processors resemble a nervous system or a huge brain, whose computing power and understanding is rapidly evolving.
At the other end of the scale, the traditional divisions between physics, chemistry, biology and electronics begin to blur. Working with technology at the scale where the fundamental processes of life take place, scientist mix tools and mechanisms across traditional boundaries between the scientific disciplines. A clear example is the research field known by the acronym NBIC – applications, where nano-tech, biotech, IT and cognitive sciences converge.

The DNA sequence of Craig Venter's artificial organism was written on a computer. It consists of long sequences of combinations of the four bases that are the building blocks of all DNA: A, C, G and T. The artificial DNA sequence is a digital file, just like a text or an image, and therefore it can be sent as an email, and, in principle, the content can be edited like you can edit any other set of digital information: by cutting and pasting. In synthetic biology, scientists are working to build large libraries of so-called "bio-bricks"; DNA sequences whose functions are so well mapped and thoroughly understood that they can be used as building blocks in the construction of new organisms with very specific properties. It's an extreme example of how the objects we create often will have both a virtual and a physical side to them.
The evolutionary drivers of such biological organisms have changed drastically. The properties of the organism have not *evolved*, but were *designed* from top to bottom with a particular intention. Moreover, the process has moved from the organic realm

and into a computer.

Complexity scientist W. Brian Arthur has summarized the development in two main trends:
- On the one hand, *technology will become more like biology*. Our creations are so complex that they are best understood and described using terms and concepts from biology. The technology increasingly behaves as if it were alive.
- On the other hand, *biology becomes more like technology*. The better scientists understand biology, the more it can be explained and manipulated, as if it were mechanical.

<u>At the edge of life</u>
Life works in ways that we have hitherto seen as fundamentally different from purely mechanical or electronic processes. Biological life works by mechanisms such as evolution, reproduction, metabolism, emotions, an ability to learn, consciousness and will.
There are, however, more and more examples of man-made technologies that posses many of these characteristics. One can speculate whether life's processes operate according to some general principles which are not limited to take place biological organisms – an example being how evolution's principle of selecting the best adapted variation seems to work the same way in relation to products launched in a market, as it does in the development of new traits of living organisms. Or how the ways a robot can learn from its experience and show emotions and preferences, are basically the same mechanisms you see at work in biological systems.

You inevitably get into longwinded debates about whether it is *really* is life, consciousness and so on, which we see emerging in our technologies. It seems an important issue to resolve, but personally I have long since chosen the strategy to put the really deep philosophy considerations aside and adopt a more practical view on the matter.

***In practical terms*, technology can behave just like life, and if we want to utilize and understand it, it often provides us a much better insight into the complex world around us if we describe it as if it were alive.**
Whether it *really* is life or just an ever better imitation of life – well, you can speculate on that, some day when there is nothing else you need to do.

<u>Our new nature – the merging of humans and technology</u>
In the Stone Age the pressure to survive was extremely hard. There was no place for weaklings. Many of us would not have survived our first year of life back then. Many of us would not even have been conceived in an age without artificial insemination. Today, however, it is not shear physical brawn, which is essential to succeed and therefore many genetic properties that would previously have been weeded out by evolution, are allowed to remain in circulation. There are also a far greater variety of genes interacting today in a world of widespread travelling and large metropolises.

Evolution is not over. Human genes continue to develop and change, often in an interesting interaction with our use of technology. When humans learned to use fire to cook food, conditions changed. You did not need such strong jaws, sharp teeth or quite so long intestines to digest food that was cooked. When man began keeping

dairy cattle, it became an advantage to be able to digest milk, and thus the genes for lactose tolerance spread in those cultures where there were cattle.
The dramatic changes in human characteristics that have occurred over the past few hundred years, however, are not due to genetic changes so much as to the improved living conditions. During the 20th century, average life expectancy in industrialized countries rose by three months a year - six hours a day! We have also become both significantly taller and heavier. In rich countries, people on average are 50 percent larger today than 250 years ago.

Culture and technology change our abilities too and it happens at a pace we can hardly keep up with. Over the last hundred years, humans have acquired such radically new properties as being able to fly and to see, talk and sense over long distances. We've become a different species thanks to technology - and we feel it first and foremost, when that technology fails. Just think of how helpless you feel if for some reason the network is down, just for a few hours. You are not quite yourself, if you are not on.
The difference between a person who is online and someone who is offline, will grow further as the device we currently call "mobile phones" over the next few years becomes a general interface for the digital world of information media, business and social networking - a kind of universal remote control and display for the gear, we are served by. The phone becomes our wallet, our keys, our newspapers, map and so on.

Having access to all the networks' information and being able to communicate to anywhere and acting at a distance in completely different worlds just by speaking some words or gesturing will be an inseparable part of our nature.
If you don't have that set of abilities - *the digital force* - you will effectively be handicapped compared to those who can participate in the digital interactions, which will be an inseparable part of what we experience as reality.

More importantly, when we are connected, we also acquire some important attributes that go beyond the individual person. Through the increasing connectivity between humans and machines we are hooking ourselves up to a new collective nervous system that acts as a technological extension of our ability to perceive, remember and think. The Internet and all the processors and devices that are connected to it will effectively work as a form of collective intelligence.

The cultural and technological evolution is where the action is

Our abilities as a species are fundamentally changed by digital technology. Bio-technology will likely change us just as radically. Our cultural development is now directly linked to our biological evolution as we - quite literally - begin to design our own genes.

The American inventor and author Ray Kurzweil says, "Evolution has changed medium". In his opinion, it is no longer biological evolution, which is the main force of change on our planet: it is the technological evolution.

In this sense, evolution is not only guiding the development of our genes. The evolutionary mechanism that drives the development of our tools is the same as the one we know from biology: variation, selection pressure and reproduction of the properties that are best suited for the current conditions. A product's success in the market, or the spread of a new idea, is also determined by diversity, selection and reproduction.

Compared with the biological evolution, there are some significant differences to the cultural and technological evolution:
- It is not necessarily based on DNA and organic chemistry.
- Technological and cultural evolution is what is called "Lamarckian", meaning that acquired characteristics can be inherited. In the biological evolution a black masons' children do not inherit the bigger upper arms that their father has built by training his muscles - but the children's ability to hammer out iron can be shaped by the technique their father teaches them. Another way of putting it is, that changes in the biological evolution are mainly transmitted *vertically* between generations, while technological and cultural changes can be transmitted *horizontally* - crisscrossing between people – or between machines. New features can be combined with elements taken from other products, and as soon as a technological component gets improved, it can be used to develop a wide range of products that incorporates the new invention.
- Technological evolution is, at least to some extent, planned and targeted. One can argue at length about whether there is a divine intelligence, which pre-planned the development of all things, but from a scientific perspective, it appears that the evolutionary mechanism is sufficient to produce the universe's incredible diversity. The raw material for biological evolution is random variation, and there is no specific direction for development. The technological evolution, however, is planned. Already Darwin pointed out that one of man's special features was our ability to think ahead, plan and thereby deliberately adapt to conditions in the future.
- Market forces largely drive technological evolution. A successful new product has to fit the consumer's needs, desires and perceptions of what has value.
- The speed of technological and cultural evolution is far higher, and in many cases it is even accelerating, as new technologies pave the way for even more advanced solutions. In the biological evolution, changes happen at the *individual* level. Every small change must be tested in real life, and the change will only stick if an organism can survive long enough to bring the new gene on to her offspring. The technological evolution, however, need not wait a whole generation to test each change, and experiences from one device can quickly be transferred to all other devices.

<u>DIY evolution</u>
Many scientists believe that humans in the course of a few hundred years have changed the conditions on the planet so fundamentally that we have reached a new geological era. The Dutch climatologist and Nobel laureate Paul Crutzen has called this new era *The Anthropocene* - the human centered era. It is not hard to see why: Our infrastructure and cities dominate the landscape, people control and appropriate a very large share of the Earth's biomass, we have changed the climate and the composition of the atmosphere and oceans, and with biotechnology, we have started modifying the genes of the most common plants and larger animals - beyond what we had already changed through traditional breeding.

As a species, human have in a very short time come to dominate and control the global ecosystem. In an evolutionary history perspective, it is unique that we as a species have now begun to steer our own evolution through our understanding of biotechnology. In this sense we have also become participants and co-creators.

There is an overwhelming scientific consensus that climate change is largely manmade and that it is intensifying. As the climate changes, we will urgently need to adapt to the changes we have caused. For this, we have a big advantage over animals and plants, which can only adapt quickly by moving to new areas. For trees, it is a slow process and for animals it can be difficult to move to new hunting grounds, because man has plastered the earth with cities and roads. At the high pace of climate change, many species will not be able to adapt. To preserve cereals, livestock and the rest of the biodiversity that supports us, humans will have to lend nature a hand in order for the biology to adapt to the new conditions, we have created.
So there is a significant interaction between the development of our technologies and the development of what is "natural" on the planet. We have taken over a large part of the responsibility for evolution.

As far back as in the sixties, the American writer and futurist Stewart Brand noted that ”we have become as Gods, so we might as well be good at it”. In 2009 Stewart Brand published the book Whole Earth Discipline in which he, in light of the challenges that humanity now faces, has adjusted his old slogan:" We have become as Gods, and we *have to* get good at it”.
We have eaten from the tree of knowledge. We are the only species on earth that can really learn, and we have built up knowledge and understanding, and thus power over our surroundings, for millennia. Whatever we do, whether we are active or passive, it makes a great difference to the planet. We are in control, and this carries a responsibility with it. The question is whether we are able to lift it?

<u>There are cyborgs living among us</u>
Some of the technologies we develop, change our circumstances so much that we even have to adapt ourselves to suit the new conditions. For example, you are not particularly fit for life in the modern society if you don’t have a cell phone, Internet access or a credit card. In a few years you will probably be lost if you are not online all the time. By then it will probably feel natural to link technology much more intimately to our body. The device that keeps us in constant contact with the network and everything it contains will leave our pocket and instead take the shape of a tiny hearing aid, a contact lens or a kind of implant - so the power to compute and communicate is no longer something we have *on* us, but *in* us.

Cyborgs are a classic ingredient of science fiction; characters that are a mixture of human and machine. But in fact, there are already many examples of people who are so closely tied to technology that their skills and their ability to get by are shaped by an intimate blend of biology and technology.
Research in supporting people who are paralyzed or are missing limbs, gives an indication of how extensive the connection between the body and the network can be. There are great efforts put into developing technologies that can decode the signals sent from the brain through nerves to activate the body's parts. In simplified terms, the idea is that you can pick up signals from nerves with electrodes and use them as input to control the movement of a prosthesis - a robotic arm or a robot leg, for example. If the person is paralyzed because a nerve path is broken, you can also try to read the signals directly from the brain and then transfer the signals to the part of the body, which is paralyzed. In this way you are creating an electronic circuit to re-connect the

brain and the body.

Another approach is to map the patterns of activity that occur in the brain when we perform an action such as lifting an arm. An application, which is currently being developed, is a wheelchair that can be controlled by thinking. It requires that the person using the chair, has his brain scanned while thinking of a variety of simple maneuvers, forward, stop, right, etc. The computer learns to recognize the pattern that occurs in the user's brain for each of the instructions that are needed. The idea is that the user can then control the wheelchair by wearing a sensing device, which, with today’s technology, resembles a swimming cap with a lot of built-in electrodes.
For over 20 years the big Japanese firm Honda has invested heavily in developing a humanoid robot known as ASIMO. One of the development projects around ASIMO is an interface that uses the same principle as the thought-controlled wheelchair, allowing a person to control the robot's movements simply by thinking of making those movements.

Once you create a connection between the nervous system and a computer, you could, in principle, be connected to *any* computer on the network. The same instructions that are sent to a wheelchair or a robot might as well steer robots anywhere on the planet - or they can control events that are purely in the digital realm, for example movements of a character in a digital graphic universe; an *avatar*.
Similarly, if we can help blind person see by sending signals from a camera directly to the optic nerve, then one could in principle send the images from any camera – or even a computer generated video. It is undeniably getting pretty complicated to discern what is real and what is artificial.

Let me emphasize that the technologies just mentioned, have all been demonstrated in practice. They are still at an experimental stage, they are relatively coarse, primitive and expensive, but as with so much other technology, there is rapid progress, partly due to a lot of research for military applications of human-computer interfaces.
Every month you can read about pioneering new concepts, and in the coming years, the convergence of humans and machines will be driven way further by the rapid development of biotechnology and nanotechnology.

<u>The One Machine</u>
The global connectivity of people seem to lead to a phase shift in which humanity collectively starts to function as a kind of global organism - a bit like the way in which an anthill can both be understood as a colony of individuals and as a coherent super-organism in which the individual ants are like cells in a body.
It seems that our machinery is following a path where, increasingly, all computers – the enormous as well the tiny – will become part of the same global network. This would in practice be one cohesive machine, and all information and all computing power will be part of it.

The writer and thinker Kevin Kelly calls it ”The One Machine”. Kelly compares the universe of data that the One Machine will encompass, with a black hole that sucks in all bits.
Every manufactured object will be involved, each and every gizmo will be connected, and all of our screens and displays will function as windows facing inwards to the same global "cloud" of information.

The Canadian media philosopher Marshall McLuhan said that technology is an extension of the human nervous system. Kevin Kelly turns it around, saying that people will be the extended senses of the machine; that everything we see and do, will become accessible to the machine.
The One Machine has several roles. You could say that it is "just" a tool, which we use to coordinate our lives, both as individuals and as a global society. However, it is not just any tool. With all the details connected in one network, the world community becomes one system: Economics, politics, fashion, knowledge etc. will evolve in sync, with all information interacting, reacting, tightly coupled and coordinated - and it would be impossible to avoid participating in the interaction.
The machine is also so advanced and powerful that it gradually begins to dominate humanity. It analyzes and draws conclusions about issues that no man would be able to calculate. We are already heavily dependent on its power.

To the extent that humanity is a global organism, The One Machine will be for humanity, what the nervous system and brain are for an individual; A fundamental necessity and an integral part of the organism's abilities and character.
The One Machine's power will change humanity, and it will change the individual. When we connect to the machine - with cell phones, sensors, through the devices we use - we become a different individual: a person with new properties and a person that to a much greater degree must be understood as part of a larger context.

Is there anyone home?
It’s controversial to call a computer "smart", but what else should we call it? Computers can analyze information and make decisions, they can translate between different languages, they can recognize faces and voices, and they can learn, so they gradually become even more proficient in performing their tasks, without needing humans to program each and every detail of their understanding.
Looking at an advanced robot can give an eerie sense of experiencing computer intelligence. We don’t perceive the robot as just a collection of dead mechanics. Seeing it move about, one gets the sense that there is an extra dimension at play: it's as if there's *something in there* - beyond the gears and electronics.

It is tempting to compare the rapid progress of robots and computers with artificial intelligence with a child who grows up and every year becomes more competent, confident and natural in its movements. Inside the brain, connections are built up, storing the experiences the child makes about how the world works. Movements, facial expressions, the meaning of words ...
It seems inconceivable that computers would not continue to become stronger, faster and more aware, that there would not be considerably more of them, and that they should not be connected ever closer together - and therefore, it seems in-conceivable that computers should not become much smarter in the future.

The technological evolution is accelerating. It’s a classic feedback loop, where new developments pave the way for the next, even faster development. As we have seen, phase shifts occur in complex systems when the interaction between the elements of the system becomes sufficiently dense. Suddenly a completely

new structure emerges and the system has acquired new features that were absent before the parts were connected.
The global network of computers has all the elements ready to make this type of phase shift. The network is increasingly complex, adaptive and dynamic, and therefore it would theoretically not be surprising if - as among the cells in a brain - a new, more advanced order of interaction should emerge; a kind of consciousness or intelligence.

<u>One day, the network will wake up and run away</u>
Should this happen, the obvious next big question is; when will the computer intelligence surpass human intelligence?
It is an important issue, both philosophical and practical, but to try to give even an approximate answer, one needs to start by making some major disclaimers: First, the intelligence that computers will have, will not be of the same nature as humans' - even if computers will eventually be able to mimic an increasing share of the type of thinking which we currently perceive as unique to humans.
Moreover, intelligence is not only a matter of raw processing power and memory size. The characteristics of our way of thinking is very much linked to our biology. We have millions of years of learning embedded in our genes, we learn with the body, and the very way the brain works, by a combination of chemical and electrical signals, is not directly comparable with the technical specifications for a computer.

Nevertheless, it is interesting to make the thought experiment. Kevin Kelly has tried to do the calculation by simply comparing the number of neurons in the human brain with the number of transistors in a computer. We have about 100 billion neurons in the brain, which comfortably exceeds the two-three billion transistors, which – at the time of writing – can be squeezed together on the most powerful computer chips. However, there is the substantial difference between the capacity of human brains and the computing power of machines, that the power of computers grows significantly every year, and that the number of processors in the world is growing rapidly, as well. Kevin Kelly estimates that if we continue to expand the use of computers at the same pace as now, the total computing power on Earth will be equivalent to six billion human brains in 2040.
By then there will be about eight billion people on the planet, so it'll be around this time that our machines' processing power has become as big as that of humanity. Of course, from there, the machine's power continues to grow exponentially further out into the sci-fi haze, right until the ultimate fusion; the day when all matter in the universe has been absorbed and integrated into the machine to be used as computing matter ...

It is possible that Kevin Kelly's estimates are a few decades off. It is possible that The One Machine will not be as strong as six billion human brains in 2040, but only as one billion brains. The important thing is not to give a precise year for when total technological convergence takes place - let alone to argue that it will indeed come to that eventually. This book is not about predicting the end result, but an attempt to understand the driving forces that we are subject to, and the potential changes that they imply.

In the previous chapter we listed seven trends for our use of information, which radically change how we interact and how we understand and experience our environment: Higher resolution, real-time information, global connectivity, geo-positioning, stored, searchable and the blending of the virtual and physical.

In addition to those changes, we can expect that our fundamental abilities and the genetic traits of our species will change at an accelerating pace. Our surroundings and the complex technologies we are creating will increasingly appear to be alive and intelligent. All in all, the world of the future is likely to become pretty exotic.
Many parts of our technology seem to be on the verge of "waking up" and changing into something completely new, a weird mix of life and mechanics with enormous power and reach, with an inhumanly great insight and immediate response which reflects a mind that is fundamentally different from our own.
"Artificial intelligence" is a poor term for the development, it would be more accurate to talk about *an animation of matter*: that all objects and in many cases even the very materials from which they are made, become sentient, thinking and connected with all other objects - and we ourselves will be an inseparable part of the tissue.

Our reality will be an inseparable mixture of physical and virtual presence. All information about everything and everyone will be part of a common, global NOW. Here and there, past and present, fact and fiction, me and we, humans and machines ... they will overlap and mix in an extremely close and extensive interconnection.

<u>The two singularities</u>
The Singularity is a term used to describe the kind of change that can happen once the machines overtake us. As the word suggests, the singularity is a unique event, so momentous that it completely changes the logic onwards.
It is clear that life in the technologically dominated future vision, I have just described, in many respects would be almost unrecognizable from the way we live today. It is a prospect that is hard to relate to. Not only is it extremely alien, but theoretically it is also a development, which might happen surprisingly soon, because the development of technology is self-reinforcing and accelerating.

In fact, there is even another singularity, which may change the conditions human life on earth just as fundamentally. The other singularity is climate change, which currently seems to be on track to undermine civilization as we know and love it.
We know the dire predictions ad nauseam: massive flooding of the most populated areas, breakdown of food production, armies of desperate climate refugees, various ecological collapse and - oh yes – growing grapes for wine in Scandinavia.
It is still a prospect that is so strange and radically different that we find it hard to relate to it as a real possibility - despite the fact that, like the extremely powerful computer network, it is a logical extension of the development we've seen so far.

We face two very strong drivers, who both have the potential to change the basic conditions for all mankind.
Interestingly, both singularities are scheduled to take place in roughly the same period. We are already noticing that both trends are growing in strength year after year, but in the decades ahead, they will definitely assert themselves as realities that cannot be ignored.
Yet we never see them systematically analyzed in combination. It is as if they are located in separate futures:
- Either: The clinical techno-world in which a giant, ubiquitous computer with ice-

cold rationality manages a civilization of cyborgs towards perpetual growth in a society that resembles a combination of a computer game and a sprawling mega-city.
- Or: The ecological collapse, where electricity and connectivity gets patchy at best, where the vacations to Thailand, the floor heating and power shopping in the supermarket are cancelled, and where we are reduced to a medieval stage of raw survival in a world of really bad weather and an awful lot of people who fight each other for the dwindling resources.

The reality, of course, is that the developments affect each other. They can reinforce or offset each other's good and nasty sides. Things can go spectacularly wrong, but hopefully, we will have more talent as stewards of the planet than that. With a little luck and a focused effort the smart technology can be used to create solutions that mitigate the worst consequences of climate change.
Maybe connectivity, combined with the necessity of a far more environmentally friendly lifestyle can even lead us to a more balanced type of growth with an emphasis on other values than pure materialism.

We can hope so. But hope is not enough. The point of this chapter is exactly that our development is no longer just a continuous adaptation to the changing circumstances, which nature offers us. To a far greater extent we will be in charge of creating our own circumstances, and even who we are. It’s an opportunity and a huge responsibility. Are we - together – up to the task?