Dr. Bertalan Mesko

Top 10 Trends Shaping The Future of Healthcare

THE MEDICAL FUTURIST

Top 10 Trends Shaping The Future of Healthcare

Dr. Bertalan Mesko

This book is for sale at
http://leanpub.com/themostexcitingnewsfromdigitalhealth

This version was published on 2017-02-01

Contents

Introduction

As The Medical Futurist, my job is to constantly analyze technological trends and find ways of implementing new solutions in everyday medicine. In this quest, I regularly publish analyses about the most exciting and promising technologies which I did in 2016 too. In this book, I feature 10 of the most interesting stories, trends and visions about the short-term future of healthcare and medicine.

It presents the latest updates on the medical use of augmented reality, artificial intelligence, robotics, genomics and even more. At the same time, it gives a picture about where we are heading in 2017.

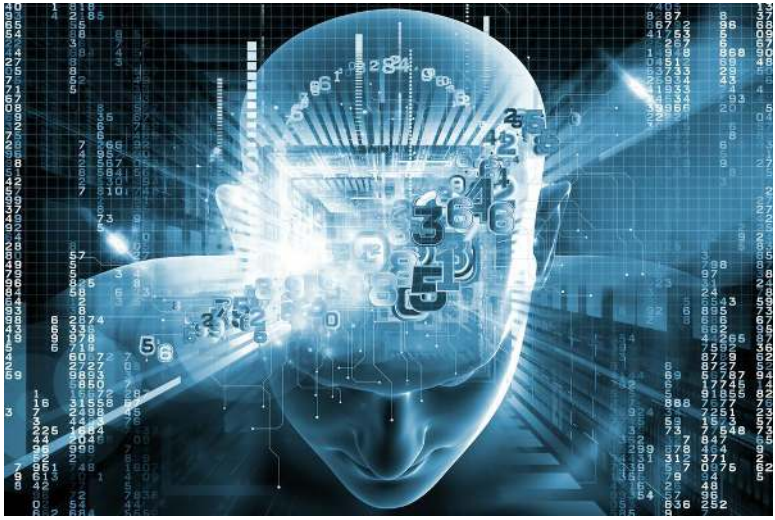
Artificial Intelligence Will Redesign Healthcare

Artificial intelligence has an unimaginable potential. Within the next couple of years, it will revolutionize every area of our life, including medicine. I am fully convinced that it will redesign healthcare completely – and for the better. Let's take a look at the promising solutions it offers.

There are various thought leaders who believe that we are experiencing the Fourth Industrial Revolution[1], which is characterized by a range of new technologies that are fusing the physical, digital and biological worlds, impacting all disciplines, economies and industries, and even challenging ideas about what it means to be human.

I am certain that healthcare will be the lead industrial area of such a revolution and one of the major catalysts for change is going to be artificial intelligence.

[1] https://www.weforum.org/pages/the-fourth-industrial-revolution-by-klaus-schwab



Big Data and Artificial Intelligence Will Revolutionize our Lives

With the evolution of digital capacity, more and more data is produced and stored in the digital space. The amount of available digital data is growing by a mind-blowing speed, doubling every two year. In 2013, it encompassed 4.4 zettabytes, however by 2020 the digital universe – the data we create and copy annually – will reach 44 zettabytes[2], or 44 trillion gigabytes (!).

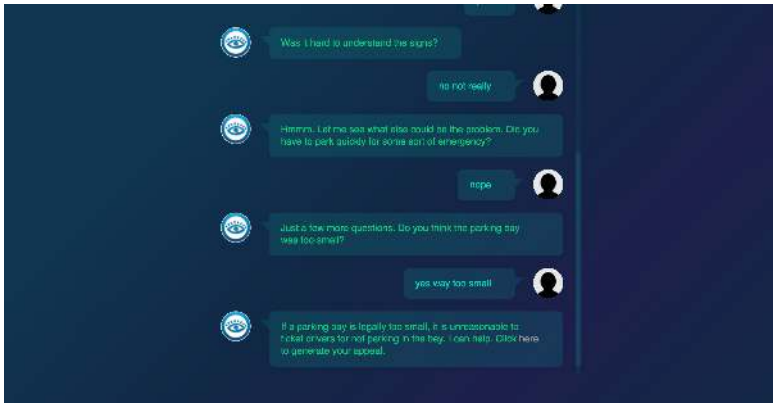
Usually, we make sense of the world around us with the help of rules and processes which build up a system. The world of Big Data is so huge that we will need artificial intelligence (AI) to be able to keep track of it.

We have not yet reached the state of "real" AI, but it is ready to sneak into our lives without any great announcement or fanfares – narrow AI is already in our cars, in Google searches, Amazon

[2]http://www.emc.com/leadership/digital-universe/2014iview/executive-summary.htm

suggestions and in many other devices. Apple's Siri, Microsoft's Cortana, Google's OK Google, and Amazon's Echo services[3] are nifty in the way that they extract questions from speech using natural-language processing and then do a limited set of useful things, such as look for a restaurant, get driving directions, find an open slot for a meeting, or run a simple web search.

But there is already more to that. A 19-year-old British programmer launched a bot last September which is successfully helping people to appeal their parking ticket.[4] It is an "AI lawyer" who can sort out what to do with the received parking ticket based on a few questions. Up until June, the bot has successfully appealed between 160,000 of 250,000 parking tickets in both London and New York, giving it a 64% success rate.



Imagine This Efficiency In Healthcare!

AI in healthcare and medicine could organize patient routes or treatment plans better, and also provide physicians with literally

[3] https://www.weforum.org/agenda/2016/06/the-open-ai-ecosystem

[4] http://www.businessinsider.com/joshua-browder-bot-overturns-160000-parking-tickets-2016-6?op=1

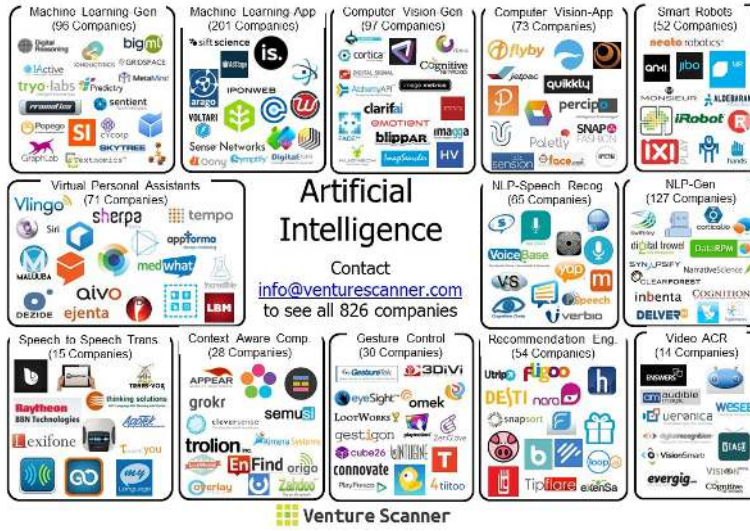
all the information they need to make a good decision.

And do not think it is the tale of the distant future. "I have no doubt that sophisticated learning and AI algorithms will find a place in healthcare over the coming years," Andy Schuetz, a senior data scientist at Sutter Health said[5]. "I don't know if it's two years or ten — but it's coming."

And as winter finally arrived in the sixth season of Game of Thrones, we should be certain that we will gradually get there. Only by looking at how many companies are interested in AI in healthcare gives the impression that it is an area with a promising future. Although IBM's Watson is the big dog in cognitive computing for healthcare, the race is on and the track is growing increasingly crowded. Dell, Hewlett-Packard, Apple, Hitachi Data Systems, Luminoso, Alchemy API, Digital Reasoning, Highspot, Lumiata, Sentient Technologies, Enterra, IPSoft and Next IT[6] – Just to mention a few names.

[5] http://www.healthcareitnews.com/news/artificial-intelligence-cognitive-computing-and-machine-learning-are-coming-healthcare-it-time

[6] http://www.healthcareitnews.com/news/artificial-intelligence-cognitive-computing-and-machine-learning-are-coming-healthcare-it-time



There are already several great examples of AI in healthcare showing potential implications and possible future uses that could make us quite optimistic.

However, these solutions will only revolutionize medicine and healthcare if they are available to the average, mainstream users – and not only to the richest medical institutions (because they are too expensive) or to a handful of experts (because they are too difficult to use).

Let's Peak Into The Future

Artificial intelligence already found several areas in healthcare to revolutionize starting from the design of treatment plans through the assistance in repetitive jobs to medication management or drug creation. And it is only the beginning.

Mining medical records:

The most obvious application of artificial intelligence in healthcare is data management. Collecting it, storing it, normalizing it, tracing its lineage – it is the first step in revolutionizing the existing healthcare systems. Recently, the AI research branch of the search giant, Google, launched its Google Deepmind Health[7] project, which is used to mine the data of medical records in order to provide better and faster health services. The project is in its initial phase, and at present they are cooperating with the Moorfields Eye Hospital NHS Foundation Trust to improve eye treatment.

Designing treatment plans:

IBM Watson launched its special program for oncologists[8] – and I interviewed one of the professors working with it[9] – which is able to provide clinicians evidence-based treatment options. Watson for Oncology has an advanced ability to analyze the meaning and context of structured and unstructured data in clinical notes and reports that may be critical to selecting a treatment pathway. Then by combining attributes from the patient's file with clinical expertise, external research and data, the program identifies potential treatment plans for a patient.

Assisting repetitive jobs:

IBM launched another algorithm called Medical Sieve[10]. It is an ambitious long-term exploratory project to build a next generation "cognitive assistant" with analytical, reasoning capabilities and a wide range of clinical knowledge. Medical Sieve is qualified to

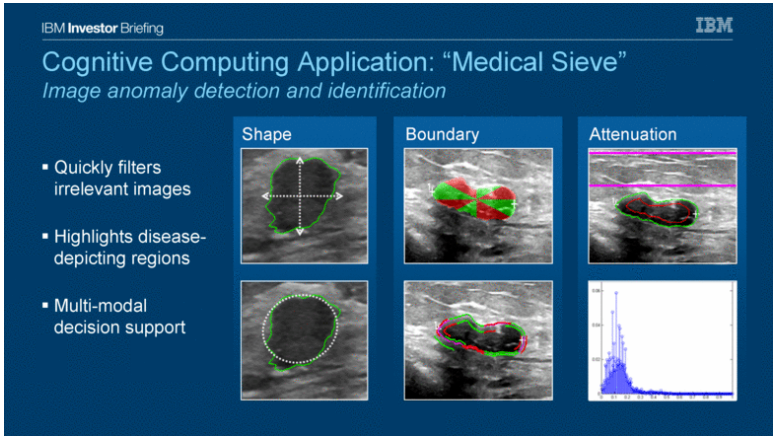
[7] https://deepmind.com/health/research

[8] http://www.ibm.com/watson/watson-oncology.html

[9] http://medicalfuturist.com/2016/07/26/what-is-using-ibm-watson-in-medicine-like/

[10] http://researcher.watson.ibm.com/researcher/view_group.php?id=4384

assist in clinical decision making in radiology and cardiology. The "cognitive health assistant" is able to analyze radiology images to spot and detect problems faster and more reliably. Radiologists in the future should only look at the most complicated cases where human supervision is useful.



The medical start-up, Enlitic[11], which also aims to couple deep learning with vast stores of medical data to advance diagnostics and improve patient outcomes, formulated the perks of deep learning the following way: "until recently, diagnostic computer programs were written using a series of predefined assumptions about disease-specific features. A specialized program had to be designed for each part of the body and only a limited set of diseases could be identified, preventing their flexibility and scalability. The programs often oversimplified reality, resulting in poor diagnostic performance, and thus never reached widespread clinical adoption. In contrast, deep learning can readily handle a broad spectrum of diseases in the entire body, and all imaging modalities (X-rays, CT scans, etc.)

[11] http://www.enlitic.com/science.html

Getting the most out of in-person and online consultations:

You have a headache, you feel dizzy and you are sure that you have a fever. Your partner tells you that you do not look great, you should go to the doctor. So, you call the assistant of your GP and ask for an appointment. It turns out you have to wait two more days to get the chance for a visit. Now, this is what's not going to happen with Babylon and its new app. The British subscription, online medical consultation and health service, Babylon[12] launched an application[13] this year which offers medical AI consultation based on personal medical history and common medical knowledge. Users report the symptoms of their illness to the app[14], which checks them against a database of diseases using speech recognition. After taking into account the patient's history and circumstances, Babylon offers an appropriate course of action. The app will also remind patients to take their medication, and follow up to find out how they're feeling. Through such solutions the efficiency of diagnosing patients can increase by multiple times, while the waiting time in front of doctor's examining rooms could drop significantly.

Health assistance and medication management:

Everybody, please welcome the world's first virtual nurse, Molly developed by the medical start-up Sense.ly[15]. It has a smiling, amicable face coupled with a pleasant voice and its exclusive goal is to help people with monitoring their condition and treatment. The interface uses machine learning to support patients with chronic conditions in-between doctor's visits. It provides proven,

[12] http://www.babylonhealth.com/

[13] http://www.babylonhealth.com/download-the-app/

[14] https://www.technologyreview.com/s/600868/the-artificially-intelligent-doctor-will-hear-you-now/

[15] http://sense.ly/?page_id=3998

customized monitoring and follow-up care, with a strong focus on chronic diseases.

Also, there is already a solution for monitoring whether patients are taking their medications for real. The AiCure app[16] supported by The National Institutes of Health uses a smartphone's webcam and AI to autonomously confirm that patients are adhering to their prescriptions, or with better terms, supporting them to make sure they know how to manage their condition. This is very useful for people with serious medical conditions, for patients who tend to go against the doctor's advice and participants in clinical trials.

Precision medicine:

Artificial intelligence will have a huge impact on genetics and genomics as well. Deep Genomics[17] aims at identifying patterns in huge data sets of genetic information and medical records, looking for mutations and linkages to disease. They are inventing a new generation of computational technologies that can tell doctors what will happen within a cell when DNA is altered by genetic variation, whether natural or therapeutic.

At the same time, Craig Venter, one of the fathers of the Human genome Project is working on an algorithm[18] that could design a patient's physical characteristics based on their DNA. With his latest enterprise, Human Longevity[19], he offers his (mostly affluent) patients complete genome sequencing coupled with full body scan and very detailed medical check-up. The whole process enables to spot cancer or vascular diseases in their very early stage.

[16] https://www.aicure.com/
[17] http://www.deepgenomics.com/
[18] http://criticalbiomass.blog.hu/2016/06/12/mutass_egy_genomot_megmutatom_ki_az
[19] http://www.humanlongevity.com/

Drug creation:

Developing pharmaceuticals through clinical trials take sometimes more than a decade and costs billions of dollars. Speeding this up and making more cost-effective would have an enormous effect on today's healthcare and how innovations reach everyday medicine. Atomwise[20] uses supercomputers that root out therapies from a database of molecular structures. Last year, Atomwise launched a virtual search for safe, existing medicines that could be redesigned to treat the Ebola virus. They found two drugs predicted by the company's AI technology which may significantly reduce Ebola infectivity. This analysis, which typically would have taken months or years, was completed in less than one day. "If we can fight back deadly viruses months or years faster that represents tens of thousands of lives," said Alexander Levy, COO of Atomwise[21]. "Imagine how many people might survive the next pandemic because a technology like Atomwise exists," he added.

Another great example for using big data for patient management is Berg Health[22], a Boston-based biopharma company, which mines data to find out why some people survive diseases and thus improve current treatment or create new therapies. They combine AI with the patients' own biological data to map out the differences between healthy and disease-friendly environments and help in the discovery and development of drugs, diagnostics and healthcare applications.

[20] http://www.atomwise.com/

[21] http://www.atomwise.com/atomwise-finds-first-evidence-towards-new-ebola-treatments/

[22] http://berghealth.com/

Open AI helping people make healthier choices and decisions:

Did you ever hear the expression, open AI ecosystem? No? Don't worry, it is rather new and a very fancy expression for connected AI infrastructures. However, the World Economic Forum named it as one of the top 10 emerging technologies in 2016[23], so it might be worth getting familiar with it. An open AI ecosystem refers to the idea[24] that with an unprecedented amount of data available, combined with advances in natural language processing and social awareness algorithms, applications of AI will become increasingly more useful to consumers.

It is especially true in the case of medicine and healthcare. There is so much data to utilize: patient medical history records, treatment data – and lately information coming from wearable health trackers and sensors. This huge amount of data could be analyzed in details not only to provide patients who want to be proactive with better suggestions about lifestyle, but it could also serve healthcare with instructive pieces of information about how to design healthcare based on the needs and habits of patients.

[23] https://www.weforum.org/agenda/2016/06/top-10-emerging-technologies-2016

[24] https://www.weforum.org/agenda/2016/06/3-ways-ai-and-robotics-will-transform-healthcare/

Analyzing a healthcare system:

97% of healthcare invoices in the Netherlands are digital containing data regarding the treatment, the doctor and the hospital. These invoices could be easily retrieved. A local company, Zorgprisma Publiek[25] analyzes the invoices and uses IBM Watson in the cloud to mine the data. They can tell if a doctor, clinic or hospital makes mistakes repetitively in treating a certain type of condition in order to help them improve and avoid unnecessary hospitalizations of patients.

What do we need to make these really happen?

First and foremost, we have to tear down the prejudices and fears regarding artificial intelligence[26] and help the general population understand how AI could be beneficial and how we can fight its possible dangers. The biggest fear is that AI will become so sophisticated that it will work better than the human brain and after a while it will aim to take control over our lives. Stephen Hawking

[25] https://www.zorgprismapubliek.nl/

[26] http://medicalfuturist.com/2016/07/12/why-people-should-not-fear-digital-health/

even said[27] that the development of full artificial intelligence could spell the end of the human race. Elon Musk agreed.

I do not think that the situation is so gloomy, but I agree with those who stress the need to prepare for the use of artificial intelligence appropriately. We need the following preparations to avoid the pitfalls of the utilization of AI:

1. creation of **ethical standards** which are applicable to and obligatory for the whole healthcare sector
2. **gradual development of AI** in order to give some time for mapping of the possible downsides
3. for medical professionals: **acquirement of basic knowledge about how AI works**[28] in a medical setting in order to 4. understand how such solutions might help them in their everyday job
4. for patients: **getting accustomed to artificial intelligence** and discovering its benefits for themselves – e.g. with the help of Cognitoys which support the cognitive development of small children with the help of AI in a fun and gentle way or with such services as Siri.
5. for companies developing AI solutions (such as IBM): **even more communication towards the general public** about the potential advantages and risks of using AI in medicine.
6. for decision-makers at healthcare institutions: **doing all the necessary steps to be able to measure the success and the effectiveness of the system**. It is also important to **push companies towards offering affordable AI-solutions**, since it is the only way to bring the promise of science fiction into reality and turn AI into the stethoscope of the 21st century.

If we succeed, huge medical discoveries and treatment breakthroughs will dominate the news not from time to time, but several

[27] http://www.bbc.com/news/technology-30290540

[28] http://medicalfuturist.com/2014/10/06/why-and-how-healthcare-institutions-should-prepare-for-ibm-watson/

times a day. If you ever come across or use a narrow AI system, you will understand my optimism.

5 Ways Medical Virtual Reality Is Already Changing Healthcare

Virtual Reality started its fascinating take-over of healthcare for the greatest pleasure of patients and doctors alike. Here are five great examples of medical VR transforming patient lives and how doctors work.

Did you know it is possible to swim with whales in the ocean while lying on a hospital bed? Have you imagined experiencing your 74th birthday as a 20-something? Perhaps followed a risky surgery from your couch?

Medical VR is an area with fascinating possibilities. It has not just moved the imagination of science-fiction fans, but also clinical researchers and real life medical practitioners. Although the field is brand new, there are already great examples of VR having a positive effect on patients' lives and physicians' work.

1) Watching operations as if you wielded the scalpel

Did you ever wonder what is going on in an operating room? What those doctors and nurses dressed in blue or green with masks on their head are doing?

For the first time in the history of medicine, on 14 April 2016 Shafi Ahmed cancer surgeon performed an operation using a virtual

reality camera at the Royal London hospital[29]. Everyone could participate in the operation in real time through the Medical Realities[30] website and the VR in OR app[31]. No matter whether a promising medical student from Cape Town, an interested journalist from Seattle or a worried relative, everyone could follow through two 360 degree cameras how the surgeon removed a cancerous tissue from the bowel of the patient.

Virtual reality could elevate the teaching and learning experience in medicine to a whole new level. Today, only a few students can peek over the shoulder of the surgeon during an operation and it is challenging to learn the tricks of the trade like that. With a virtual reality camera, surgeons can stream operations globally and allow medical students to actually be there in the OR using their VR goggles.

[29] https://www.theguardian.com/technology/2016/apr/14/cutting-edge-theatre-worlds-first-virtual-reality-operation-goes-live

[30] http://www.medicalrealities.com/

[31] http://vrinor.com/

2) Relaxing chronic patients with Medical VR

Have you ever lain down on a hospital bed counting the days until you are released? Did you, as a patient ever have the feeling that time just stops in the hospital, there is nothing to do, you miss your family and friends and you are constantly worried about your condition?

Brennan Spiegel and his team at the Cedars-Sinai hospital in Los Angeles introduced VR worlds to their patients to help them release stress and reduce pain. With the special goggles, they could escape the four walls of the hospital and visit amazing landscapes in Iceland, participate in the work of an art studio or swim together with whales in the deep blue ocean.

Spiegel says that not only can the hospital experience be improved with medical VR, but the costs of care may also be reduced. By reducing stress and pain, the length of the patient's stay in the ward or the amount of resources utilized can both be decreased.

A similar project called Farmoo was developed by enthusiastic university students[32]. As its main creator, Henry Lo says "it is intended to help teen cancer patients get distracted during chemotherapy treatments so that they can focus more on the activities inside the game, rather than the treatment itself.

3) Making children feel like they're at home

The experience in a hospital is even more stressful and mentally burdening for small children who miss their parents, their best

[32] http://www.the-peak.ca/2016/05/sfu-students-design-virtual-reality-game-for-cancer-patients/

buddies, their favourite blanket and generally, the soothing environment called home.

Now, a Dutch company made their dreams possible. Through a smartphone and virtual glasses, VisitU[33] makes live contact possible with a 360 degree camera at the patient's home, school or special occasions such as a birthday celebration or a football game. Though hospitalized, young patients can relax and still enjoy their lives.

Through Medical VR, it might become easier for relatives and friends to maintain relations with their loved once in hospital care since the lengthy drives to the hospital could be spared, making room for more quality time spent together.

[33] http://visitu.nl/

4) Helping physicians experience life as an elderly

Did you ever wonder how it feels like to grow old? How it feels like to not be able to lift your hand above your head? How it feels like when you've lost one of your fingers, or recover from a heart attack?

Embodied Labs created "We Are Alfred"[34] by using VR technology to show young medical students what ageing means. Everyone can be the hypothetical Alfred for 7 minutes, and experience how it feels like to live as a 74 year-old man with audio-visual impairments.

The developers' ultimate goal is to solve the disconnection between young doctors and elderly patients due to their huge age difference. Fostering empathy between caretakers and their charges is much easier when physicians can see things from the patients' perspectives.

5) Speeding up recovery after a stroke

For patients who survived a stroke or traumatic brain injury, time is of the essence. The earlier they start rehabilitation, the better chances they have for successfully regaining lost functions.

MindMotionPro, produced by the Swiss Mindmaze allows patients to "practice" how to lift their arms or move their fingers with the help of virtual reality. Although they might not carry out the actual movement, the app enhances attention, motivation and engagement with visual and auditory feedback. The app makes the practice of repetitive movements fun for patients. The resulting mental effort helps their traumatized nervous systems to recover much faster than lying helplessly in bed.

[34] http://www.upworthy.com/how-do-you-make-a-young-doctor-really-understand-what-its-like-being-74-virtual-reality?c=huf1

Augmented Reality In Healthcare Will Be Revolutionary

Augmented reality is one of the most promising digital technologies at present – look at the success of Pokémon Go – and it has the potential to change healthcare and everyday medicine completely for physicians and patients alike.

By now, it is official: Pokémon Go conquered the world. TechCrunch[35] reported that on the day when the game was launched, it immediately surpassed the daily time usage of Facebook, SnapChat or Twitter by the average iOS user on mobile phones. Tom Curry[36], a man living in New Zealand quit his job to become a full-time Pokémon hunter. In Central Park, herds of Pokémon Go players almost caused a stampede as they tried to capture a rare type of the imagined animal.

[35]https://techcrunch.com/2016/07/13/pokemon-go-tops-twitters-daily-users-sees-more-engagement-than-facebook/

[36]https://www.theguardian.com/technology/2016/jul/15/pokemon-go-man-quits-job-to-become-full-time-pokemon-hunter

Rafael Grossmann, the first surgeon who performed an operation with the help of Google Glass, told me that Pokémon Go represents the ultimate gamification of an "activity" app, and that he does not think the inventors of the game such as Nintendo expected nor planned this effect in people.

So why is the game so popular and what does it have to do with the future of medicine?

The response is augmented reality (AR) and the rising interest of people in its use. Pokémon Go is made with exactly this technology: the device (in this case your phone) transmits a live or indirect view of a physical, real-world environment which is augmented by computer-generated sensory input such as sound, video, graphics or GPS data. In the future, augmented reality could be a built-in feature in a glass, headset or digital contact lens.

Augmented reality differs from its most known "relative", virtual reality (VR) since the latter creates a 3D world completely detaching the user from reality. There are two respects in which AR is unique: users do not lose touch with reality and it puts information into

eyesight as fast as possible. These distinctive features enable AR to become a driving force in the future of medicine.

At the moment, there are certain hindrances to overcome but Grossmann thinks that AR and VR will be very common in healthcare within the next 3-5 years. According to Grossmann, the biggest obstacles are related to education, cultural change and acceptance, but the technical obstacles are absolutely temporal and not an issue at all, and cost-related barriers will also disappear in the future.

So, let me show you the best examples of augmented reality in medicine.

1) Augmented reality can save lives through showing defibrillators nearby

What would you do if a person next to you collapsed suddenly? All kinds of thoughts would rush through your head, and no matter whether you would think of calling an ambulance, a doctor or your mom for help, you would definitely reach for your phone.

And I suggest you to consider downloading the Layar reality[37] browser combined with AED4EU[38] app to your phone next to the basic emergency numbers so the next time you get into a similar situation, you will be able to help more.

AED4EU was created by Lucien Engelen[39] from the Radboud University Nijmegen Medical Centre, The Netherlands. Its users can add places where automated external defibrillators or AEDs are located and this database can be accessed through this new application. Moreover, with the Layar browser, you can project the exact location of the nearest AEDs on the screen of your phone

[37] https://www.layar.com/
[38] http://www.aed4.eu/
[39] http://twitter.com/zorg20

and it would take a minute to find them and help those in need. So augmented reality brings crucial pieces of information to those in need or danger.

2) Google Glass might help new mothers struggling with breastfeeding

It is a matter of fact that Google Glass has the potential to revolutionize healthcare, but to be honest I would have never thought of the possibility of helping new mothers with breastfeeding through this technology.

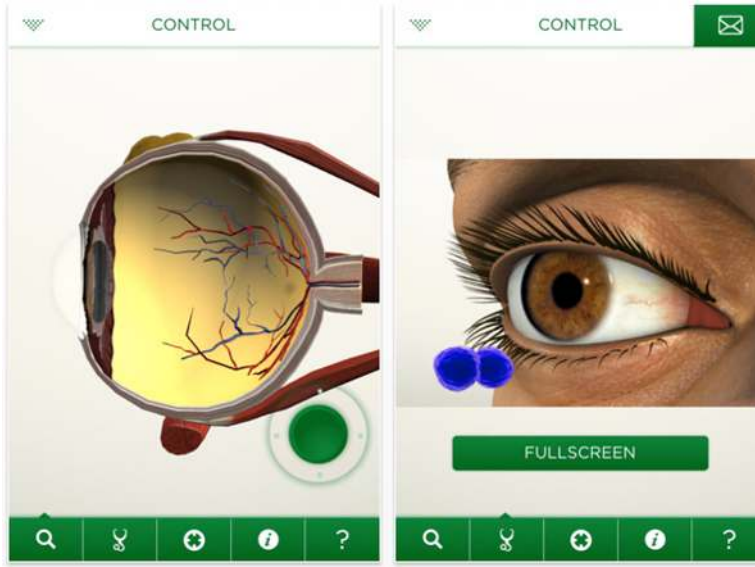
In 2014, the Melbourne office of an innovation company called Small World conducted a Google Glass trial with the Australian Breastfeeding Association that effectively allowed their telephone counsellors to see through the eyes of mothers while they breastfed at home. Through such a way struggling mothers could get expert help at any time of the day and they did not even have to put down the baby from their arms. By sharing the patient's perspective, consultations get to a new level.

3) Patients can describe their symptoms better through augmented reality

Patients often struggle when they have to describe their symptoms to their doctors accurately. In other cases, people often find themselves overreacting a medical situation or on the contrary, belittle the problem. In ophthalmology, augmented reality might be the answer for patient education.

EyeDecide[40] is one of its kind medical app, which uses the camera display for simulating the impact of specific conditions on a person's vision. Using apps like EyeDecide, doctors can show simulation of the vision of a patient suffering from a specific condition. For instance, the app can demonstrate the impact of Cataract or AMD and thus helping patients understand their symptoms and their actual medical state. If patients can experience the long-term effects of their lifestyle on their health, it could motivate people to make positive changes.

[40] https://itunes.apple.com/us/app/eye-decide-patient-engagement/id454280553?mt=8



4) Nurses can find veins easier with augmented reality

The start-up company AccuVein[41] is using AR technology to make both nurses' and patients' lives easier. AccuVein's marketing specialist, Vinny Luciano said[42] 40% of IVs (intravenous injections) miss the vein on the first stick, with the numbers getting worse for children and the elderly. AccuVein uses augmented reality by using a handheld scanner that projects over skin and shows nurses and doctors where veins are in the patients' bodies. Luciano estimates that it's been used on more than 10 million patients, making finding a vein on the first stick 3.5x more likely. Such technologies could assist healthcare professionals and extend their skills.

[41] http://www.accuvein.com/2015/11/accuvein-cited-as-a-premier-augmented-reality-application/

[42] http://themarketmogul.com/next-big-trend-augmented-reality/

5) Motivating runners through zombies

Imagine that you are walking through a dark and abandoned alley, and you suddenly hear the groaning and the slow movement of a strange creature. I am pretty sure that even the laziest person would speed up after realizing that a "real zombie" is after him. This is the basic idea behind the Zombies, Run![43] application.

The game monopolizes on the fact that fear can motivate people and the fact that everything seems to be more fun when turned into a game. This app is perfect for those who consider running a boring activity. If you not only hear but also see virtual zombies projected onto your phone or device's screen, you will not only increase your speed and endurance, but also feel that time is just flying by.

6) Pharma companies can provide more innovative drug information

Have you ever been curious about how a drug works in your body? Even if you got interested in discovering how the distant world of pills and medicaments work, I bet you lost all your enthusiasm after you read the boring and undecipherable drug description. Now, augmented reality is here to change it.

With the help of AR, patients can see how the drug works in 3D in front of their eyes instead of just reading long descriptions on the bottle[44]. Lab workers could monitor their experiments with augmented reality equipment. In factories, workers could start working without hands on trainings as the device would tell them what to do, and how to do it.

[43] https://zombiesrungame.com/

[44] http://medicalfuturist.com/2016/04/26/6-surprising-trends-shaping-the-future-of-pharma/

7) Augmented reality can assist surgeons in the OR

Doctors and even patients are aware of the fact that when it comes to surgery, precision is of prime importance. Now, AR can help surgeons become more efficient at surgeries. Whether they are conducting a minimally invasive procedure or locating a tumor in liver, AR healthcare apps can help save lives and treat patients seamlessly.

Medsights[45] Tech developed a software to test the feasibility of using augmented reality to create accurate 3-dimensional reconstructions of tumors. The complex image reconstructing technology basically empowers surgeons with x-ray views – without any radiation exposure, in real time.

The earlier mentioned Grossmann, who was part of the team performing the first live operation using medical VR[46], told me that HoloAnatomy, which is using HoloLens to display real data-anatomical models, is a wonderful and rather intuitive use of AR having obvious advantages over traditional methods.

8) Google's digital contact lens can transform how we look at the world

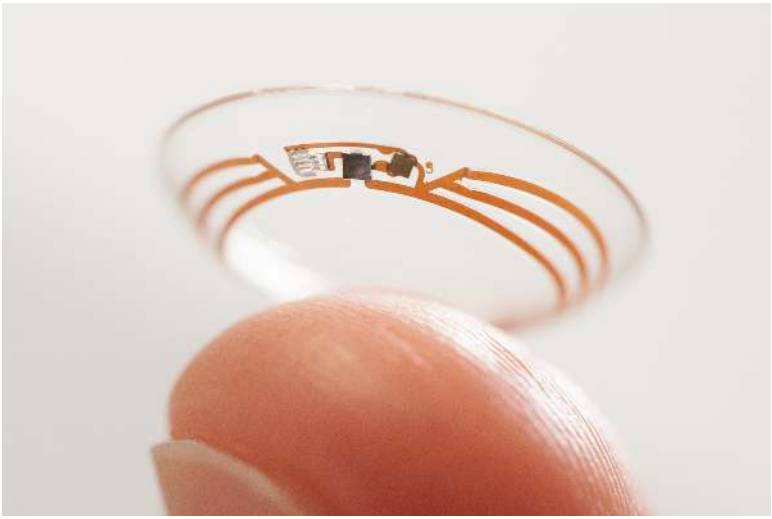
The age of digital contact lenses and retinal implants are upon us and they have great potential in transforming healthcare. Retinal implants might give vision back to those who lost it or grant humans supervision augmenting what we can do. Digital contact lenses could transform both how we look at the world while also revolutionizing diabetes care. Google aims to produce digital, multi-sensor contact lens[47] which will be able to measure blood sugar

[45] http://www.medsightstech.com/

[46] http://medicalfuturist.com/2016/06/21/5-ways-medical-vr-is-changing-healthcare/

[47] http://medicalfuturist.com/2016/04/07/googles-amazing-digital-contact-lens-can-transform-diabetes-care/

levels. On the other hand, diabetes care constitutes rather a side feature, while more importantly digital contact lenses will be able to augment reality – for example to turn the page of an e-book by blinking an eye.



Although current devices such as Microsoft Hololens[48] are far from the "perfect" experience[49], but there is no reason to believe that we will not get there soon. Thus, the most effective way to get used to this future trend, if we start to educate ourselves and our children.

Do you remember which your favorite toy as a kid was? For example, I always had a passion for LEGO. Assembling little LEGO-parts into something new, creating castles, cars, complex cities – that is one of the best activities in the world. It stimulates your fantasy, your creativity, develops your skills for holistic vision as well as your attention to detail. Lately, there are various videogames which attempt to recreate LEGO in the virtual space – such as Minecraft.

[48] http://www.theverge.com/2016/4/1/11334488/microsoft-hololens-video-augmented-reality-ar-headset-hands-on

[49] http://www.medgadget.com/2016/07/hololens-hands-want.html

Parents often complain that their kids are just sitting in from of some screens not learning anything about their environment and themselves, but I do not agree. Minecraft also enhances creativity, develops the way children see the world around them – but in a different way as LEGO. I think that from here, it is only one leap before we reach LEGO with AR where the advantages of building something in the real world might be combined with virtual imagination. This way, our kids would be able to know what real is real, but would also be ready to exploit the opportunities AR can provide us with.

I think it would be a great way to get accustomed to the future since I do believe augmented reality is the future. If you still do not believe me, just look at those people chasing Pokémons on the streets.

Top 10 Healthcare Wearables For A Healthy Lifestyle

There are thousands of devices and gadgets on the healthcare wearable market which could help you live a healthier and better life, although it is not easy to choose. Let me show you my top choices when it comes to health wearables and trackers.

Thus, I know that finding the right healthcare wearable is a struggle. Sometimes technology in itself does not provide much help. For example, the Amazon Wearable marketplace[50] has so many devices, it makes even harder to choose. Also, there are many problems you might encounter. A bunch of technological problems might arise: the device requires constant attention, needs to be charged constantly, Bluetooth connections unpair randomly and synchronization might be a nightmare. And when you finally "master" technology, it takes the skills of an IT guru combined with that of a trained physician to interpret the data. Some makers of healthcare wearables are better than others[51] at providing insight into how to live better instead of dumping meaningless data in the users' lap.

But first of all, let me help you with finding the best health trackers and wearables. As the The Medical Futurist, I'm objective but as an experienced Quantified Selfer, I have my own choices which might also help you to live more healthily.

---

[50] https://www.amazon.com/Wearable-Technology/b?ie=UTF8&node=10048700011

[51] http://medicalfuturist.com/2015/07/07/101-commandments-for-companies-developing-wearable-health-trackers

1) For having the best night's sleep

You surely know from the tale of Sleeping Beauty that the survival of empires could depend on a good night's sleep. Research shows sleep is very important to brainpower, health, beauty or overall well-being. Sleep trackers usually measure when you fall asleep, wake up and how much time you spend in deep-sleep. The latter is the most important, for me. For some people, how well-rested they feel depends on how much sleep they get. For others, it only depends on the amount of deep-sleep. As it's pretty personalized, everyone needs to find their own solution. You can download my guide for a better sleep here[52].

My choice:

Pebble Time[53]: measuring your sleep is only one of the built-in health tracking applications available to the Pebble Time family[54] of smartwatches. Developed by Pebble in collaboration with researchers at Stanford University, Pebble Health[55] automatically tracks when you go to bed, displaying sleep, deep-sleep, and the times when you fall asleep and wake up.

Android Sleep App[56]: this useful app can pair with your sleep tracker and wake you up at the best possible time so you're rested and don't feel groggy at all. The app can wake you with nature sounds, soothing music, captcha or puzzle alarms. It also helps you track your sleep, deep-sleep and warns you if you are running on a sleep deficit. The app even pays attention to the sound in the room while you are sleeping to catch you snoring, record you talking in your sleep, or help you diagnose sleep illnesses.

[52] http://medicalfuturist.com/2015/11/26/how-i-optimized-my-sleep-with-technology/

[53] https://www.pebble.com/health

[54] http://medicalfuturist.com/2015/10/08/the-pebble-time-smartwatch-review/

[55] https://help.getpebble.com/customer/portal/articles/2239065-pebble-health?b_id=8308

[56] http://lifehacker.com/5993005/five-best-sleep-tracking-gadgets-or-apps

2) For staying fit and energetic

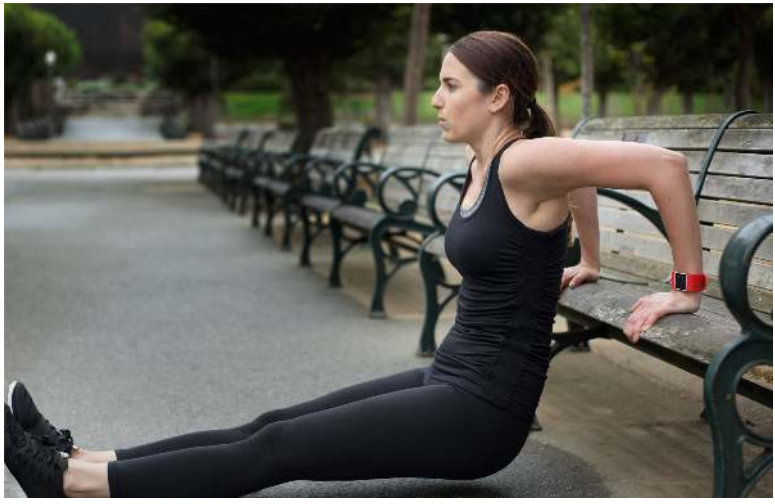
The most popular and widely known healthcare wearables are the fitness and sport activity trackers. Most smartphones already have built-in apps for measuring how many steps you take a day, whether you run (even to catch the bus) or bike. The activity trackers might also measure your pulse rate and create colorful graphs and charts to help you figure out the best ways to keep fit and healthy.

My choice:

Fitbit Surge[57]: Of all the brands of fitness trackers on the market, Fitbit is the best-known, and for good reason. This touch-screen wristwatch not only tracks your steps and sleep, but also alerts you to incoming phone calls and text messages, keeps tabs on your heart rate with a built-in optical heart rate monitor and uses GPS

[57] https://www.fitbit.com/eu/surge

to track outdoor activity. GPS is especially useful, as you don't have to take your phone with you when you run or bike to track exercise. The tracker is reliable, easy to use and connects you to a great community with whom you can share your activities and even compete for the first place earned by the fittest.



3) For getting rid of stress in your life

Stress is one of the biggest health risks in the 21st century's busy environment, full of constant impulses and distractions. As you probably know, stress might lead to heart disease, obesity, diabetes, gastrointestinal problems, headaches, anxiety – and even asthma. It reduces your level of focus, leads to bad sleep and decreases emotional well-being. It affects everyone – and I'm no exception. However, stress can be fought successfully with the help of technology.

My choice:

PIP[58]: a tiny device designed to give immediate feedback about your stress levels. Its smartphone app helps you learn how to reduce stress by having you transform a depressing scene into a happy one by actively relaxing, giving you tips along the way. You just hold the PIP device between the thumb and index fingers to measure skin conductivity for a few minutes. The longer you can keep stress low, the faster the scene changes.

The task takes me about 15 minutes, while my wife does it in about 4 minutes.[59] Of course it stresses me to think C>about how much more stressed I am than my wife, at least according to the device. But I am working on it.

[58]https://thepip.com/en-eu/

[59]http://o%20http//medicalfuturist.com/2016/02/04/fight-stress-successfully-with-technology-free-guide-and-giveaway/

4) For keeping blood pressure optimal

Hypertension is one of the most common chronic conditions throughout the world. In the United States, nearly 80 million Americans have high blood pressure[60]. Many clinicians and patients use home blood pressure monitors to help manage high blood pressure, helping with everything from medication titration to supporting lifestyle modification.

My choice:

Withings Blood Pressure[61]: one of the earliest connected devices available on the market. It consists of an app connecting through Bluetooth to the blood pressure monitor itself. The app measures your heart rate, blood pressure and also counts the steps you take weekly. The Withings' several useful features include the ability to set the monitor to take three measurements and report the average, which is consistent with medical recommendations. You can also set up reminders for various issues from taking your blood pressure to taking your medications.

[60] http://www.imedicalapps.com/2015/02/physician-review-withings-blood-pressure-monitor/

[61] https://www.withings.com/eu/en/products/blood-pressure-monitor

5) For keeping track of your weight

For some people, measuring weight might constitute an unpleasant daily activity since obtaining and keeping optimum weight is one of the greatest challenges for many, in an age when people often assume the "perfect body image" equals success and health. It definitely does not, but weight still constitutes an important factor to our health. As you know, obesity might lead to heart disease, diabetes, high blood pressure and even stroke or cancer. On the other hand, being too skinny also leads to health problems such as anemia, low immune system or fertility issues. Thus, it is very important to find your optimum weight, right body mass index (BMI) and to measure it on a regular basis.

My choice:

Fitbit Aria[62]: it is the latest smart gadget of the Fitbit-family. The smart scale tracks your weight and body fat percentage – preferably daily – and uploads the information to a cloud-based account over your home Wi-Fi network. The Fitbit Aria can sense up to eight different people, using historical data to work out who is whom. The best part for me is that it is connected to my FitBit account therefore I see my weight changes compared to the physical activity I have.

[62] https://www.fitbit.com/eu/aria

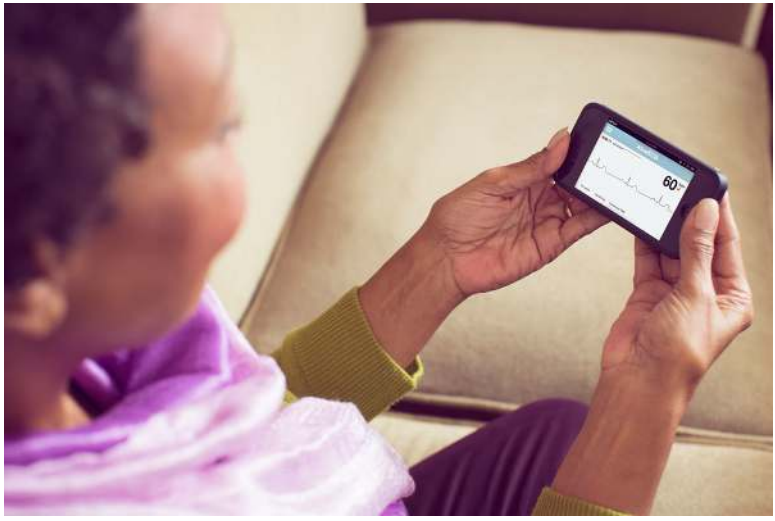
6) For keeping your heart healthy

Your heart beats around 100,000 times per day. If you allow smart gadgets to access, track and analyze your heart's health, you can

predict and even prevent a host of problems, including serious diseases such as a sudden heart attack.

My choice:

AliveCor Heart Monitor[63]: a mobile phone based electrocardiogram. The tiny, slim and simple device attaches to your phone case. Its app has three main divisions: ECG recording, collected data, and a great educational portion. A great use for the AliveCor Heart Monitor[64] is during an experience of symptoms that you have described to your physician in the past. Palpitations, for example, can come and go at random, and relevant data from the actual episodes yields helpful insights for healthcare providers.



[63] https://www.alivecor.com/en/

[64] http://www.medgadget.com/2014/04/alivecor-heart-monitor-a-smartphone-powered-ecg-product-review.html

7) For measuring your body temperature effectively

An optimal body temperature is important. You surely remember vividly when you fell sick as a child, and the first thing your mom did was check your temperature – which took long minutes of sitting still with a clinical thermometer stuck to your tongue or in your armpit. Luckily, recent innovations allow you to measure temperature in a fast and frustration-free way.

My choice:

Viatom Checkme[65]: the world's first medical tricorder[66], a proper medical multitool. It not only measures your body temperature, but also traces ECG, measures pulse rate and rhythm, oxygen saturation, systolic blood pressure, physical activity and sleep[67]. It only takes a second for the device to determine whether you have a fever and should visit your physician, or you are completely healthy and can continue your day as planned.

[65] http://www.viatomtech.com/#!checkme-pro/c1mv2
[66] http://www.viatomtech.com/#!checkme-pro/c1mv2
[67] http://www.rifthealth.com/world-exclusive-viatom-checkme-tricorder-review-1/

8) For helping to meditate effectively

As you already know, managing stress is vital to your health. There are many ways to effectively reduce your stress level, and you should definitely spend time finding the best possible way to do so. A popular method is meditation, which has been scientifically shown to reduce symptoms associated with stress, depression and anxiety. Although you might not want technology messing with your brain; it might actually help you to reach a calm and relaxing state of mind easier.

My choice:

Muse headband[68]: the brain sensing headband helps you get the most out of your meditation practice by giving you real time biofeedback of what is going on in your mind. The Muse is not some

[68] http://www.choosemuse.com/

dystopian headset trying to alter your brain. Instead its makers, InteraXon want to train you to alter it yourself[69]. The routine is simple. You put the Muse headset on, you complete the breathing exercises to the sound of waves (neutral), storms (bad) and tweeting birds (good) which indicate how focused and calm you are. If your mind is too active, the Muse gives you feedback to help you clear your thoughts.

9) For exercising in the most effective way possible

If the tons of information coming from every possible media channel, magazine and common sense cannot convince you about the health benefits of exercising, neither can I. However, you should know that according to the US National Cancer Institute[70], leisure-

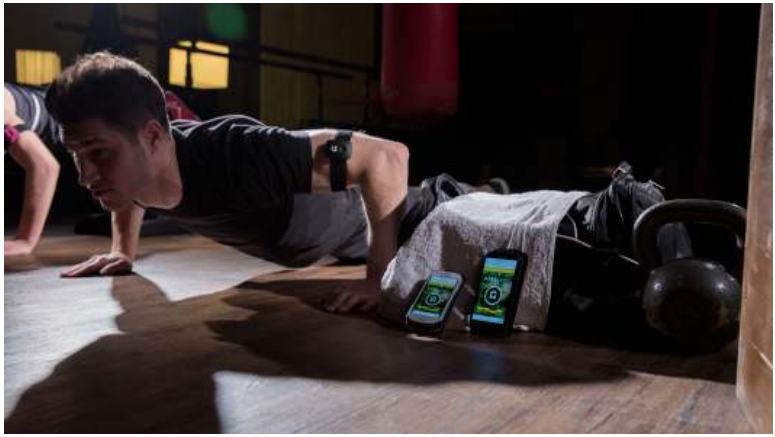
[69] http://www.wareable.com/wearable-tech/muse-brain-sensing-headband-review-938

[70] http://www.cancer.gov/news-events/press-releases/2012/PhysicalActivityLifeExpectancy

time physical activity is associated with longer life expectancy. And it does not matter whether you like to use the treadmill, do cross-fit or aerobic, some healthcare wearables can help you make the most of the exercises.

My choice:

Gymwatch Fitness Tracker[71]: GymWatch is a fitness tracker that is not about counting steps. Rather, it wants to become your personal fitness coach or your professional performance diagnostician. This is a wearable that is built for the gym, specifically for people that head straight for the weights. Worn on the arm or on the leg, it helps you build muscle in the correct way and makes sure you are completing those reps properly. The tracker gives you visual and verbal, real-time feedback[72], and also connects you with its community of like-minded fitness enthusiasts.



[71] https://www.gymwatch.com/

[72] http://www.wareable.com/fitness-trackers/gymwatch

10) For improving your general well-being

A mistake people often make when wanting to use technology to live better is rushing to buy a wearable device. Devising a way to optimize your life is up to you. A wearable can only show you data, which won't be actionable if you don't know what should be changed. I advise you to start by scoring your mental, physical and emotional health in a simple Excel or Google spreadsheet. Despite my numerous devices, I still use such a spreadsheet every day.[73] It helped me to understand how my body works, and understanding the problem itself is the first step towards the solution. Living better starts with vigilance about our health rather than using technology.

I hope you will start upgrading your health and that you find useful methods and motivation in my experience.

[73] http://medicalfuturist.com/2015/06/09/top-10-health-parameters-you-can-measure-at-home/

Shall We Sequence Genomes At Home? – The Future of Genomics

As a geneticist, talking with George Church or the President of the Personalized Medicine Coalition was a fascinating experience while writing my recently published book, The Guide to the Future of Medicine[74]. This is still one of the most promising fields of medicine but without getting it closer to the general public, genomics will never play a pivotal role in practicing medicine.

Let's start from the beginning. From the years of 2005, 2006 and 2007, patients have been able to order genetic tests online with 23andme, Navigenics or Pathway Genomics. In 2013, 23andme received a letter from FDA[75] about ceasing marketing of the screening service. Since then, the market has been transforming into something new that could also meet the regulations of the FDA. At least, hopefully.

[74] http://amzn.to/1w0O3sx

[75] http://www.theguardian.com/science/2013/nov/25/genetics-23andme-fda-marketing-pgs-screening

I've had 3 genomic tests with Navigenics[76], Pathway Genomics[77] and My Gentle Labs[78] with 3 different results and experience. I thought the direct-to-consumer (DTC) market is just not ready for prime time. I also analyzed my own raw data with Promethease[79] and got to very interesting conclusions about the future of my life. I loved the possibility to get insights about my genome as well, not just measuring my vital signs. Here is my overall experience with genetic testing:

Similarly to how the wearable revolution is transforming into a world of smart clothes, disease prevention and insideables (swallowed sensors), the field of DTC genomics has been changing too. Here are some reasons why.

- While the **cost of sequencing** one person's genome was about $3 billion in 2003, now it's possible[80] for under $1-3000

[76] http://scienceroll.com/2009/03/07/navigenics-what-my-genome-tells-me-to-do/
[77] http://scienceroll.com/2010/03/19/pathway-genomics-lets-see-my-genes/
[78] http://scienceroll.com/2014/04/15/gentle-2/
[79] https://promethease.com/ondemandlicense
[80] http://www.genome.gov/sequencingcosts/

(see figure below). The $1000 genome is still not here, but the trends are clear and soon the shipping cost of the sample will be higher than actually sequencing that genome.

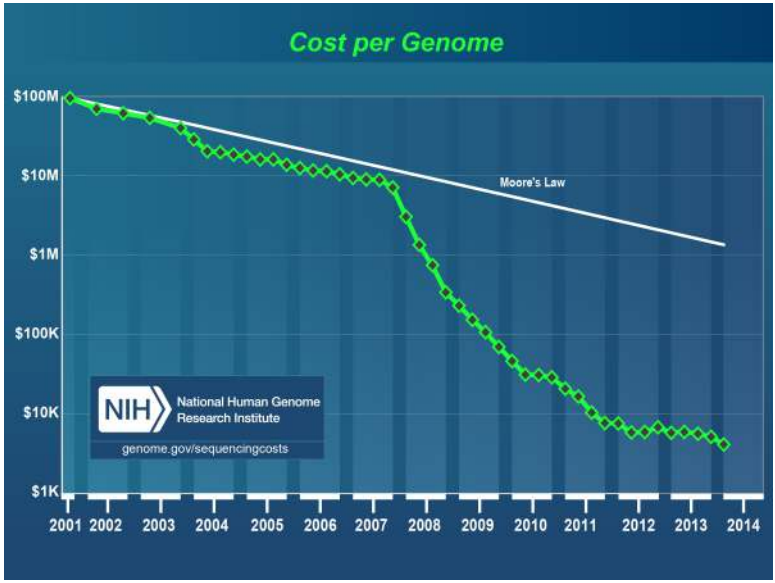
- The **number of sequenced genomes** is skyrocketing. Illumina said[81] that 228,000 Human Genomes would be sequenced only in 2014 and the predictions for this year are even bigger. Soon we will all have access to our own genomes.
- It is known that **fetal DNA** is circulating in the mother's blood,and it can be separated[82] from her blood to allow analysis of the fetus's genetic makeup. Imagine the possibilities.
- Large US hospitals are about[83] to begin **sequencing the genomes of healthy newborn babies** as part of a government-funded research program called BabySeq. Major diseases could be pointed out and precautions could be made about others far in time.
- Oxford Nanopore developed[84] the **MinION™ portable device** for molecular analyses of DNA, RNA and proteins that is driven by nanopore technology. It might be the first step towards sequencing genes at home, despite early criticisms.
- There are more and more **targeted cancer therapies** available. As certain tumors have specific genetic mutations such as BRCA in breast cancer or EGFR in lung cancer, among others, they might be sensitive to targeted drugs. Sequencing a tumor's own genome is becoming a routine step in designing the therapy for cancer patients, although the costs are exceptionally high.

[81] http://www.technologyreview.com/news/531091/emtech-illumina-says-228000-human-genomes-will-be-sequenced-this-year/

[82] https://en.wikipedia.org/wiki/Cell-free_fetal_DNA

[83] http://www.wsj.com/articles/genome-sequencing-in-babies-to-begin-as-part-of-study-1419896152

[84] https://www.nanoporetech.com/



As you can see, examples underscore the notion that genomics could play a very important role in everyday medicine, but numerous steps and elements are needed for that.

1. Comprehensive and thorough **regulation** from organizations such as the FDA or EMA about what DTC companies can offer and actually do. Can patients order tests online or only their caregivers?
2. **Innovative companies** connecting patients to medical professionals through the genomic knowledge behind cancer and other diseases.
3. **Reliable algorithms** that could help use the huge amount of data genome sequencing leads to in analyzing health outcomes. A great example[85] is how Joel Dudley at Mount Sinai Medical Center is working on implementing big data

[85] http://www.technologyreview.com/news/518916/a-hospital-takes-its-own-big-data-medicine/

in medical decision making. IBM Watson is also analyzing[86] genomic data to find treatments in brain cancer.

4. With the **widespread** of genetic testing and the decline in the cost, it should be a common thing to analyze my genome or get a detailed analysis. Moreover, caregivers should be trained to be able to use that data in patients' health or disease management.
5. A **better understanding** of what genomics can and cannot offer by the general public. Professor Church pointed out to me that without educating people about the pros and cons of the genomic revolution, we cannot make the right steps forward.

It has become clear, seeing the trends, that the technology letting us sequence genomes at home is coming. Although it's still hard to make good, evidence-based decisions purely based on genetic background; to get reimbursed if genetics-based personalized treatments are cost-effective on the long term (but expensive on the short term); and to interpret the huge amount of data. Cognitive computers are meant to help us with that, but I'm sure ever-improving technologies will provide all of us with our own genomes far before we could do anything with that information.

[86] http://www.research.ibm.com/articles/genomics.shtml

For How Long Will We Test Drugs On Patients?

Clinical trials today are long and expensive. Pharma companies spend billions of dollars and still, at the end of the day a drug might not become approved. On the one hand, this creates a huge risk for them to invest into innovation, on the other hand patients sometimes have to wait for unnecessarily long until a new drug reaches the market.

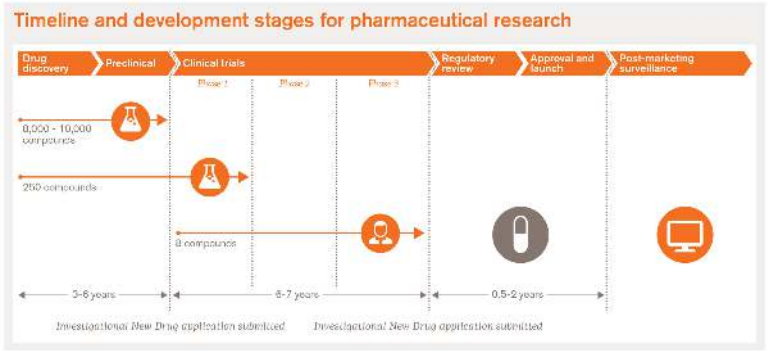
The Sisyphean task called human clinical trial

I honestly hate sitting on panel discussions. I like offering solutions to problems through my keynotes, but panel discussions rarely provide a chance for that. Still, I accept invitations and sit on these panels with the thought that you never know when you'll get a challenging question. At an event organized by the pharmaceutical industry, I sat with representatives from major pharma companies. I had given a talk about how disruptive innovations would transform the pharma industry entirely. To my surprise there were patients in the audience.

One patient directed his question about human testing to another member of the panel. I was glad because I covered the issue in my talk and wanted to hear what pharma representatives had to say about it. Current pharma models involve a lengthy and expensive process of clinical trials whose purpose is to assess the safety and efficacy of potential new drugs.

New drugs are approved through human clinical trials. These are

rigorous, starting in animal trials and gradually moving to patients. It typically costs billions of dollars and takes many years to complete, sometimes more than a decade. Patients in trials are exposed to side effects that cannot be predicted or expected. If the trial is successful, it may or may not receive approval of the respective regulatory agency, e.g. the US Food and Drugs Administration (FDA).



If a pharmaceutical company jumps through all the hoops and wins approval, they can sell their new product for a limited time under patent protection. If it does not win approval all their investment goes down the drain.

How can we change the process?

There are two lines of thoughts concerning possible changes to the system. There are many who would like to improve the existing system, and there are those who see the future of clinical trials in something completely different, rather revolutionary, the so-called in silico trials.

Technology to assist clinical trials

One way to help clinical trials is through various online services which make it possible for more and more patients to participate in the process of drug creation. TrialReach[87] tries to bridge the gap between patients and researchers who are developing new drugs. If more patients have a chance to participate in trials, they might become more engaged with potential treatments or even be able to access new treatments before they become FDA approved and freely available. TrialX[88] similarly matches clinical trials to patients according to their gender, age, location, and medical condition. The number of such services is growing to accommodate an increasing demand from patients.

An unexpected hindrance to the success of clinical trials is linked to transportation. Although in the United States, patients who decide to participate in clinical trials often get taxi vouchers and bus passes to enable them to show up at trial sites. However, more often than not, it is still not enough for patients to actually show up. So ridesharing companies such as Uber or Lyft decided to help[89].

[87] http://trialreach.com/

[88] http://trialx.com/

[89] http://www.mobihealthnews.com/content/uber-lyft-gear-help-get-patients-clinical-trial-sites

Uber recently launched its Circulation[90] initiative to get patients to clinical trial sites, using a system that allows trial organizers to coordinate rides themselves in a software backend so they know exactly where the patient is. The patient interacts with the system via text message. And Lyft launched a similar initiative.

In the United States, also the government supports actively the improvement of clinical trials. Investigators at the University of Utah, School of Medicine's Data Coordinating Center have been awarded in 2016[91] a seven-year, $25 million grant from the National Center for Advancing Translational Sciences (NCATS) of the National Institutes of Health, to form one of three Trial Innovation Centers (TIC) to improve clinical research. Their goal is three-fold: (1) to eliminate and help actors get through the obstacles of bureaucracy in initiating multicenter trials and to comply with national policies; (2) to support the development and implementation of practical study protocols within feasible budgets and (3) to support for randomized drug trials, including industry-sponsored trials.

The rapid development of artificial intelligence might also aid clinical trials – with AI they might require significantly less time and they might be brought closer to the medical institutions and patients themselves. For example the company, Atomwise[92] uses supercomputers that root out therapies from a database of molecular structures. Last year, Atomwise launched a virtual search for safe, existing medicines that could be redesigned to treat the Ebola virus. They found two drugs predicted by the company's AI technology which may significantly reduce Ebola infectivity. This analysis, which typically would have taken months or years, was completed in less than one day. Imagine how efficient drug creation would become if such clinical trials could be run at the "ground zero" level of healthcare, namely in pharmacies.

[90] http://circulation.co/

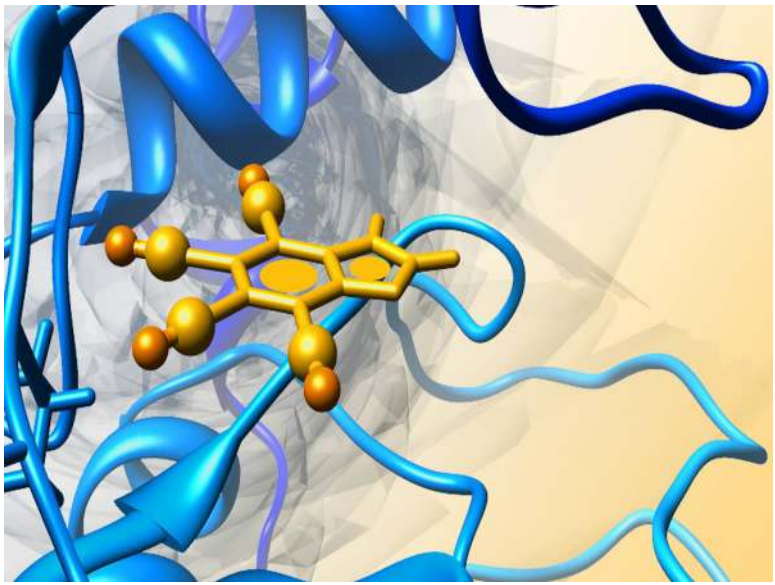
[91] http://www.eurekalert.org/pub_releases/2016-07/uouh-dcw072916.php

[92] http://www.atomwise.com/

Are in silico trials the future?

And what if we take a radical turn? What if it is time to use disruptive innovations to change how clinical trials are performed? Imagine the following: neither animals, nor humans are the subject of the lengthy and costly drug creation process, but their characteristics are so perfectly simulated that the clinical trial can be carried out in less time, with less money and still amazing results. This method is called an in silico trial.

An in silico clinical trial is an individualized computer simulation used in the development or regulatory evaluation of a medicinal product, device, or intervention. While completely simulated clinical trials are not feasible with current technology and understanding of biology, its development would be expected to have major benefits over current in vivo clinical trials, and research on it is being pursued.



Imagine if we could test thousands of new potential drugs on billions of virtual patient models in minutes? What would it take to achieve such a capability? At the very least, the virtual patients must almost perfectly mimic the physiology of the target patients, with all of the variation that actual patients show. The model should encompass circulatory, neural, endocrine, and metabolic systems, and each of these must demonstrate valid mechanism–based responses to physiological and pharmacological stimuli. Probably cognitive computers would be needed to deal with the gargantuan amount of resulting data.

HumMod[93] is one of the most advanced simulations in this respect. It provides a top–down model of human physiology from whole organs to individual molecules. It features more than 1,500 equations and 6,500 variables such as body fluids, circulation, electrolytes, hormones, metabolism, and skin temperature. HumMod aims to simulate how human physiology works, and claims to be the

[93] http://hummod.org/

most sophisticated mathematical model of human physiology ever created. HumMod has been in development for decades and it is still far from completion. It may take decades to get there.

Might Organs-on-Chips offer help with clinical trials?

Maybe supplementary technologies are needed. The Organs-on-Chips technology[94] is able to use stem cells to mimic organs of the body with a series of devices. Many experts believe that this technology could revolutionize clinical trials[95] and replace animal testing completely. Organs-on-Chips are engineered to mimic how the lung or the heart works at the cellular level. They are translucent, and so can provide a window into the inner workings of a particular organ. The Wyss Institute[96] plans to build ten different

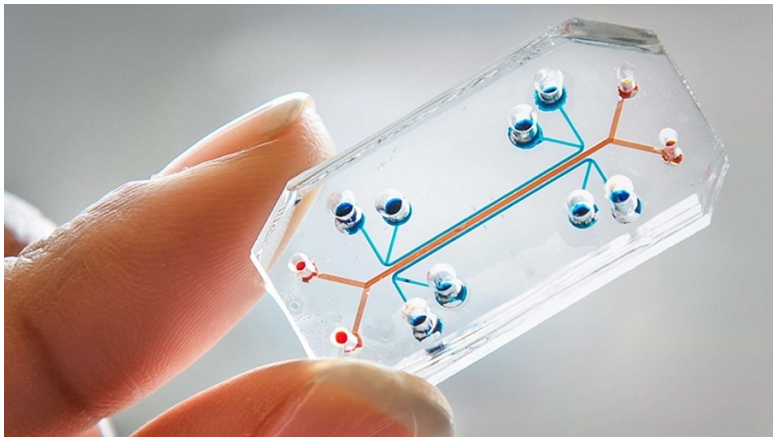
[94] http://wyss.harvard.edu/viewpage/461/

[95] http://www.meddeviceonline.com/doc/human-organ-mimicking-chip-could-revolutionize-clinical-trials-0001

[96] http://wyss.harvard.edu/

organs–on–chips and connect them together. Doing this may mimic whole–body physiology better, and thus better assess responses to new drug candidates.

However, we should note that although the experiments are promising, these are still far from a real and total-body simulation of human physiology. Even if organs could be mimicked, connecting the models to each other is more complicated than we would think.



Food for thought

After the members of the panel had tried to break the question of human testing into smaller pieces, I jumped in and said I hoped that technology will soon allow us to test drugs not on patients but in silica. You might assume that developing the supercomputers for this or simulating the wonderfully complex human body on a chip are the biggest challenges to bring this about. But I think the biggest obstacle will be the resistance of pharma companies and authorities that do not like to change a very old process.

Also, we need to ensure absolute safety for patients. We need to make sure any in silico finding is suitable to be used in practice. But I

am confident I will tell my kids in a decade or so that when I became a medical doctor in 2009, we used to test drugs on patients. It was a barbaric era of medicine until artificial intelligence, supercomputers and organ-on-chip technologies came along.

Twelve Things We Can 3D Print in Medicine Now

The list of objects that have been successfully printed out in 3D demonstrates the potential this technology holds for the near future of medicine.

Kaiba Gionfriddo[97] was born prematurely in 2011. After 8 months his lung development caused concerns, although he was sent home with his parents as his breathing was normal. Six weeks later, Kaiba stopped breathing and turned blue. He was diagnosed with tracheobronchomalacia, a long Latin word that means his windpipe was so weak that it collapsed. He had a tracheostomy and was put on a ventilator––the conventional treatment. Still, Kaiba would stop breathing almost daily. His heart would stop, too. His caregivers 3D printed a bioresorbable device that instantly helped Kaiba breathe. This case is considered a prime example of how customized 3D printing is transforming healthcare as we know it.

Since then this area has been skyrocketing.

Tissues with blood vessels: Researchers at Harvard University were the first to use a custom–built 3D printer and a dissolving ink to create a swatch of tissue that contains skin cells interwoven with structural material interwoven that can potentially function as blood vessels.

Low–Cost Prosthetic Parts: Creating traditional prosthetics is very time–consuming and destructive, which means that any modifications would destroy the original molds. Researchers at the University of Toronto, in collaboration with Autodesk Research and CBM Canada, used 3D printing to quickly produce cheap and

[97] http://www.medicalnewstoday.com/articles/263218.php

easily customizable prosthetic sockets for patients in the developing world.

Drugs: Lee Cronin, a chemist at the University of Glasgow, wants to do for the discovery and distribution of prescription drugs what Apple did for music. In a TED talk he described a prototype 3D printer capable of assembling chemical compounds at the molecular level. Patients would go to an online drugstore with their digital prescription, buy the blueprint and the chemical ink needed, and then print the drug at home. In the future he said we might sell not drugs but rather blueprints or apps.

Tailor–made sensors: Researchers have used scans of animal hearts to create printed models, and then added stretchy electronics on top of those models. The material can be peeled off the printed model and wrapped around the real heart for a perfect fit. The next step is to enhance the electronics with multiple sensors.

Tumor Models: Researchers in China and the US have both printed models of cancerous tumors to aid discovery of new anti–cancer drugs and to better understand how tumors develop, grow, and

spread.

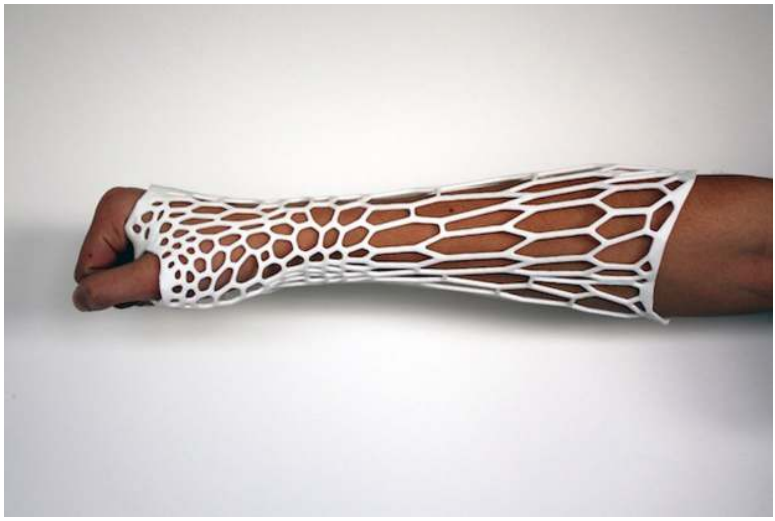
Bone: Professor Susmita Bose of Washington State University modified a 3D printer to bind chemicals to a ceramic powder creating intricate ceramic scaffolds that promote the growth of the bone in any shape.

Heart Valve: Jonathan Butcher of Cornell University has printed a heart valve that will soon be tested in sheep. He used a combination of cells and biomaterials to control the valve's stiffness.

Ear cartilage: Lawrence Bonassar of Cornell University used 3D photos of human ears to create ear molds. The molds were then filled with a gel containing bovine cartilage cells suspended in collagen, which held the shape of the ear while cells grew their extracellular matrix.

Medical equipment: Already, 3D printing is occurring in underdeveloped areas. "Not Impossible Labs" based in Venice, California took 3D printers to Sudan where the chaos of war has left many peo-

ple with amputated limbs. The organization's founder, Mick Ebeling, trained locals how to operate the machinery, create patient–specific limbs, and fit these new, very inexpensive prosthetics.



Cranium Replacement: Dutch surgeons replaced the entire top of a 22 year–old woman's skull with a customized printed implant made from plastic.

Synthetic skin: James Yoo at the Wake Forest School of Medicine in the US has developed a printer that can print skin straight onto the wounds of burn victims.

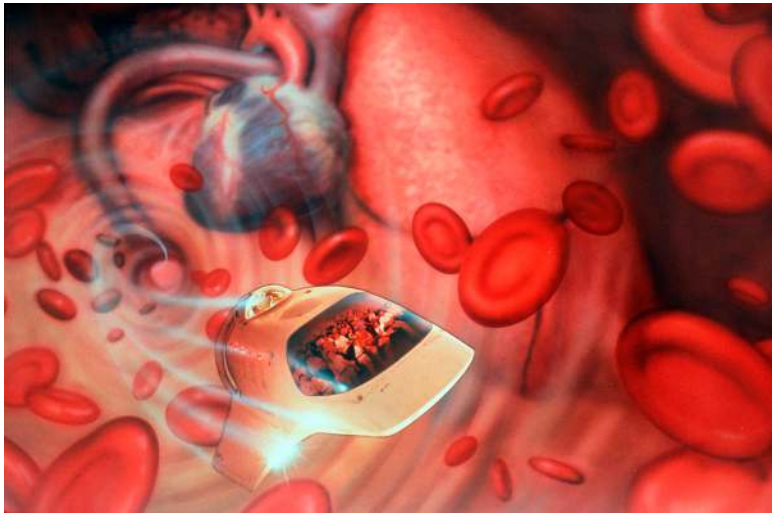
Organs: Organovo just announced that their bioprinted liver assays are able to function for more than 40 days. Organovo's top executives and other industry experts suggest that within a decade we will be able to print solid organs such as liver, heart, and kidney. Hundreds of thousands of people worldwide are waiting for an organ donor. Imagine how such a technology could transform their lives.

Nanotechnology in Healthcare: Getting Smaller and Smarter

We are living at the dawn of the nanomedicine age. I believe that nanoparticles and nanodevices will soon operate as precise drug delivery systems, cancer treatment tools or tiny surgeons. Let me introduce you the brave, new world of nanotechnology in healthcare.

Nanorobots having nanobreakfast with your red and white blood cells

When I was a kid, one of my favorite TV series was a French animation, *Il était un fois… la vie* (1986). I found it fascinating how the creators imagined the human body as a construction where tiny cars floated through the human veins, grab-cranes worked on teeth and bacteria as tiny monsters tried to attack innocent screaming lady-cells, while white blood cells defended the body as well-trained soldiers. Somehow similarly, the 1966 movie, *Fantastic Voyage* explored shrinking a medical team to microscopic size in order to save a renowned scientist's life. The Argonauts travel through the bloodstream into the brain where the crew uses a laser gun to blast away a blood clot.

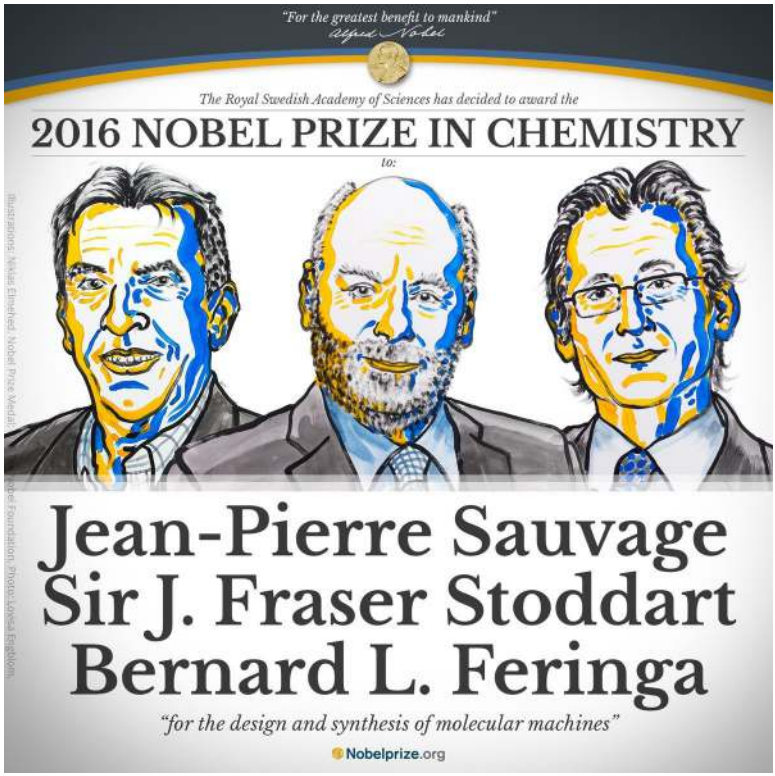


Now, imagine that all this could happen in real life… How about a nanometer sized cage that lets out insulin but doesn't get attacked by our immune system? How about a nanorobot delivering dopamine directly to the brainstem for treating Parkinson's disease? And how about injecting chemotherapy into cancer cells while keeping healthy cells untouched? Could you imagine microscopic robots inside you sending alerts to your smartphone that a disease is about to develop in your body? In such a scenario, the word symptom would be completely eradicated from our medical dictionaries.

Sounds like an idea out of a science-fiction novel?

If you think that nanorobots and engineered nanoparticles are only part of the world created by Jules Verne or by Greg Egan in his novel, *Diaspora*, you might not heard about the winners of the 2016 Nobel Prize in chemistry. It was awarded to brilliant scientists Jean-

Pierre Sauvage[98], Sir J. Fraser Stoddart and Bernard L. Feringa[99], very simply for having developed molecules with controllable movements. As Gizmodo acknowledges, although molecular nanotechnology is still in its infancy, by awarding the Nobel Prize to these three scientists, the Royal Swedish Academy of Sciences is acknowledging nanotechnology's huge potential.



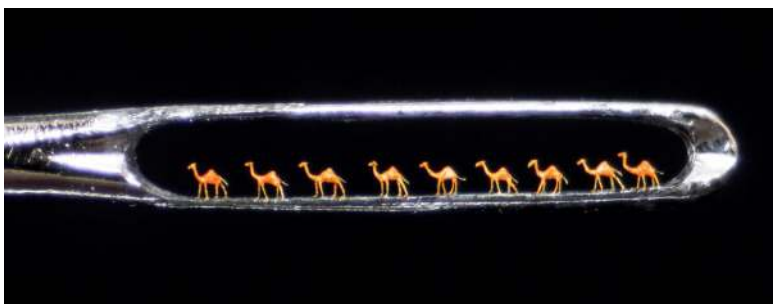
[98]https://en.wikipedia.org/wiki/Jean-Pierre_Sauvage
[99]https://en.wikipedia.org/wiki/Ben_Feringa

So, how did nanotechnology arrive at its current state and how will it change the notion of healthcare in the future?

"Nano" means smaller than micro-sculptures on pin-point

Nanotechnology is hardly comprehensible by the average human mind, because it is in a completely different dimension. Somewhere at the molecular and atomic level. Do you remember the micro-sculptures in the eye of a needle[100]? Compared to the nanometer, the basic unit of measurement in nanotechnology, these are still huge. A nanometer is a million times smaller than the length of an ant.[101] A sheet of paper is about 100, 000 nanometers thick. The ratio of the Earth to a child's marble is roughly the ratio of a meter to a nanometer.

Essentially, nanotechnology comprises science, engineering and technology conducted at the nanoscale, which is about 1 to 100 nanometers. It is basically manipulating and controlling materials at the atomic and molecular level. Amazing, right?



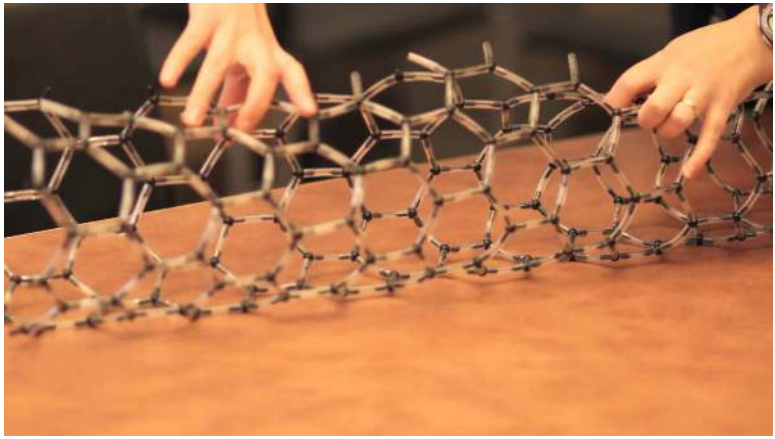
[100]http://www.telegraph.co.uk/news/picturegalleries/howaboutthat/5505943/Artist-Willard-Wigan-creates-micro-sculptures-that-fit-in-the-eye-of-a-needle.html?image=1

[101]http://singularityhub.com/2016/05/16/nanorobots-where-we-are-today-and-why-their-future-has-amazing-potential/?ct=t(Newsletter_2014_07_177_17_2014)

The Story of Nanotechnology – From tiny "demons" to nanorobots in bloodstreams

As part of an 1871 thought experiment Scottish physicist James Clerk Maxwell imagined tiny "demons" that could redirect atoms one at a time. However, it was a long way to go from there until the birth of nanotechnology. The term molecular engineering was actually coined by MIT professor Arthur Robert von Hippel in the 1950s. On the evening of December 29, 1959, the famous physicist Richard Feynman described in his after–dinner lecture at the annual meeting of the American Physical Society how the entire Encyclopaedia Britannica could be written on the head of a pin, and how all the world's books could fit in a pamphlet.

Continuing the thought experiment, Kim Eric Drexler, an MIT undergraduate in the mid–1970s, envisioned that molecule–sized machines could manufacture almost anything. In his book, Drexler described nanotechnology's future role in revolutionizing other areas of science and technology that would lead to breakthroughs in medicine, artificial intelligence, and astronomy. His idea of an "assembler" could "place atoms in almost any reasonable arrangement," thus allowing us to build almost anything that the laws of nature will allow.



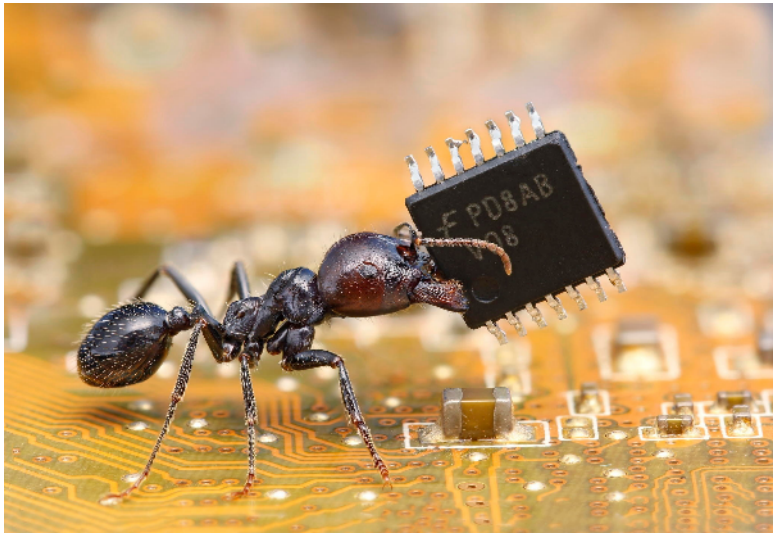
Later, in 1991 carbon nanotubes were discovered, which are about 100 times stronger than steel only one–sixth their weight, and have unusual heat and conductivity characteristics. The Juno spacecraft currently on its way to Jupiter[102] uses carbon nanostructure composite to provide electrical grounding, discharge static, and reduce weight. From the beginning it was inevitable that this technology would be used in medicine. Now, we are about to reach this point.

All kinds of nano under the microscope

Nanotechnology has two basic strands. The first one is the Drexlerian molecule-sized machine, which is able to build and manipulate its environment at the atomic level. The second one is "biological" nanotech[103], which basically uses DNA and the machinery of life to create unique structures made of proteins or DNA (as a building material).

[102] http://www.space.com/topics/nasa-juno-jupiter-mission-news

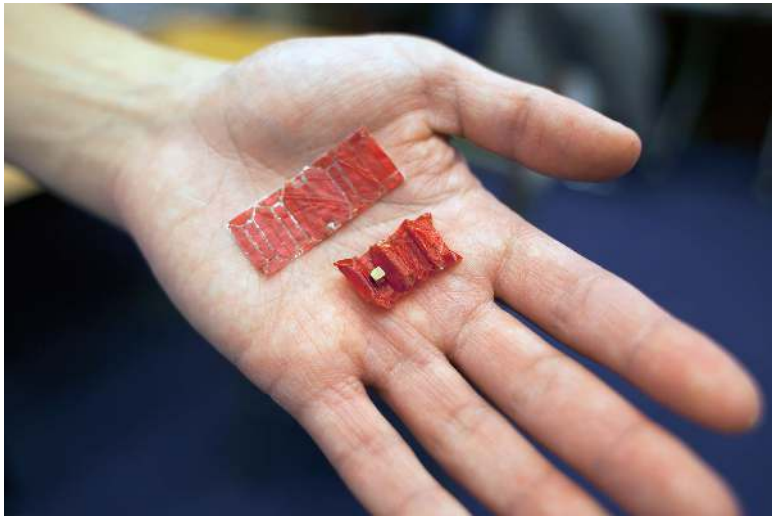
[103] http://singularityhub.com/2016/05/16/nanorobots-where-we-are-today-and-why-their-future-has-amazing-potential/?ct=t(Newsletter_2014_07_177_17_2014)



1) DNA-based origami robots

One of the most forward–thinking experiments proved that DNA–based nanorobots can be inserted into a living cockroach[104] and later perform logical operations upon command such as releasing a molecule stored within it. Such nanorobots are also called origami robots since they can unfold and deliver drugs, could eventually be able to carry out complex programs including diagnoses or treatments. One of the most astonishing feats is the accuracy of delivery and control of these nanobots, which are equivalent to a computer system. The other one is that the same basic design principles that apply to typical full-size machine parts can also be applied to DNA.

[104] http://www.iflscience.com/health-and-medicine/dna-strands-used-create-origami-nanobots-inside-cockroaches/



2) Scallop-like microbots and nanoswimmers

Researchers from the Max Planck Institute have been experimenting with exceptionally micro-sized – smaller than a millimeter – robots that literally swim through your bodily fluids[105] and could be used to deliver drugs or other medical relief in a highly-targeted way. These scallop-like microbots are designed to swim through non-Newtonian fluids, like your bloodstream, around your lymphatic system, or across the slippery goo on the surface of your eyeballs.

ETH Zurich and Technion researchers[106] have developed an elastic "nanoswimmer" polypyrrole (Ppy) nanowire about 15 micrometers (millionths of a meter) long and 200 nanometers thick that can move through biological fluid environments at almost 15 micrometers per second. The nanoswimmers might be programmed to deliver drugs

[105] http://www.gizmag.com/scallop-microbots-swim-body-max-planck/34589/

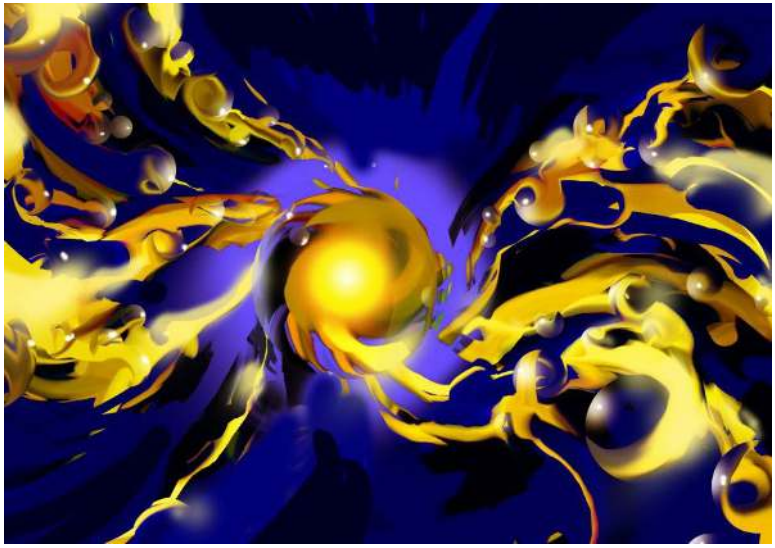
[106] http://www.kurzweilai.net/magnetically-controlled-nanoswimmer-could-deliver-drugs-via-bloodstream

and magnetically controlled to swim through the bloodstream to target cancer cells, for example.

3) Ant-like nanoengines

Ant–like robots are controlled magnetically, are very fast, can locate, and use tools. Moving through even flexible surfaces they can construct three–dimensional structures at an amazing pace. They could revolutionize both biotechnology and electronics manufacturing.

University of Cambridge researchers have developed the world's tiniest engine, made of gold nanoparticles bound together with temperature-responsive gel polymers, capable of a force per unit-weight nearly 100 times higher than any motor or muscle. Researchers named the nanomachine ANT, since as real ants, they produce large forces for their weight.



4) Sperm-inspired microrobots

A team of researchers at the University of Twente (Netherlands) and German University in Cairo has developed sperm-inspired microrobots[107] called MagnetoSperm that can be controlled by weak oscillating magnetic fields. When the 322 micron-long robot is subjected to an oscillating field of less than five millitesla — about the strength of your touristy fridge magnet from Manhattan — it experiences a magnetic torque on its head, which causes its flagellum to oscillate and propel it forward.

MagnetoSperm can be used to manipulate and assemble objects at nanoscales using an external source of magnetic field to control its motion. In the future, researchers hope to further scale down the size of the microrobot. The team is currently working on a method to generate a magnetic nanofiber that can be used as a flagellum.

[107] http://www.kurzweilai.net/sperm-inspired-microrobots-controlled-by-magnetic-fields

5) Bacteria-powered robots

Drexel University engineers have developed a method[108] for using electric fields to help microscopic bacteria-powered robots detect obstacles in their environment and navigate around them. It means that robots navigate with the help of electric fields, and they can be programmed into getting to a certain point or changing its route or avoid/go through objects.

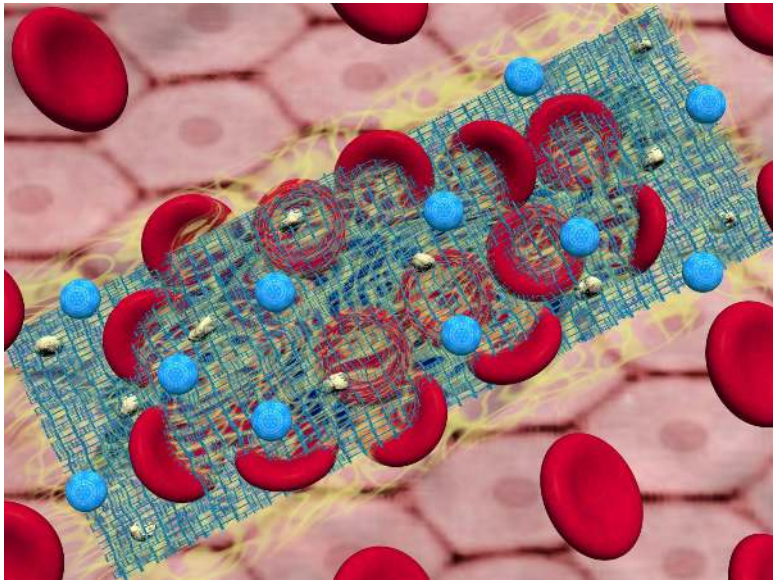
Bacteria-powered robots might bring amazing changes in healthcare, which include delivering medication exactly to the point where it is needed, manipulating stem cells to direct their growth, or building a microstructure, for example.

6) Clottocyte nanorobots

I know the word "clottocyte" sounds strange, it means artificial mechanical platelet[109]. These nanorobots function similarly to platelets that stick together to form a blood clot that stops bleeding. They could store fibers until they encounter a wound, and then disperse them to create a clot in a fraction of the time that platelets do. Blood–related microbivore nanorobots act like white blood cells, and could be designed to be faster and more efficient at destroying bacteria or similar invasive agents.

Thus, bacterial or viral infections could be eliminated from someone in a matter of minutes as opposed to the days required for antibiotics to take effect. Nanobots would also not have their potential side effects. So instead of taking medicine or having an injection after having got the flue, you just go to the pharmacy, ask for a non-prescription clottocyte nanorobot, and the flue is gone by the time you are out of the door.

[108] http://www.kurzweilai.net/electrical-control-of-bacteria-powered-microrobots
[109] http://www.imm.org/publications/reports/rep018/



7) Respirocyte nanorobots

These tiny little creatures act like red blood cells, but they would have the potential to carry much more oxygen than natural red blood cells do for patients suffering from anemia (when the body does not have enough healthy red blood cells). They might also contain sensors to measure the concentration of oxygen in the bloodstream. One day blood may become both a repository and symbiosis of nanorobots and our human cells.

How can we use the army of nanorobots?

The real advantage of having robots on the nanometer scale is having them work in large groups. One miniscule robot cannot make much of a difference. But a million of them might move the Golden Gate Bridge.

1) The most accurate drug delivery systems

The greatest potential in nanodevices lies in their ability to deliver drugs to the exact location where they are needed. There are many diseases – including cancer – where treatment causes lots of serious side-effects exactly because the active substance in the medication cannot differentiate between healthy and diseased tissues. In the future, nanotechnology could provide a great solution.

Imagine vaccine delivery with microneedle patches instead of taking drugs or having to suffer through injections! Microneedle

patches could provide cheaper, simpler, and safer methods of delivery compared to traditional administration that requires skilled professionals and runs the risk of infection. Microneedles at micron–scale are coated with a dry formulation of vaccine that dissolves in the skin within minutes after applying the patch. Scientists proved that measles vaccine can be stabilized on microneedles and is comparably effective to the standard subcutaneous injection.

Imagine programmable nanoparticles, which might help tackle the day-to-day miseries of chronic diseases, such as diabetes. They might deliver insulin to initiate cell growth and regenerate tissue at a target location. In case of neurodegenerative diseases such as Parkinson's, nanodevices could deliver drugs, implant neurostimulators, or transport intelligent biomaterials across the blood–brain barrier in order to direct regeneration within the central nervous system.

2) The greatest chance to treat cancer successfully

As a very simple explanation, cancer occurs when cells refuse to die and keep multiplying in various places in our bodies, while hiding from our immune systems. Currently, the most effective treatments against cancer comprise various forms of radiation and chemotherapy, which stops the regeneration procedure for cells. The problem with chemotherapy and radiation is that it cannot be utilized in targeted ways, therefore it has serious, sometimes even life-threatening side-effects. The use of nanotechnology might mean a revolution in cancer treatment.

Creating drugs that directly attack cancer cells without damaging other tissues has already been proven to be a safe method in treating cervical cancer. Swedish researchers have developed a technique that uses magnetically controlled nanoparticles to force tumor cells to self–destruct without harming surrounding tissue

radiation and chemotherapy do. It is primarily intended for cancer treatment, although it could be used for other diseases including type 1 diabetes.

3) Nanoparticles as information managers and surgeons

Nanodevices might be programmed into gathering information about certain body parts, levels of toxins and other substances inside our bodies and then "report" back to the medical professionals or to its "hosts". In the future, it might become reality that a nanorobot sends alerts to your smartphone that your glucose level is high, you need to take insulin. Nanoparticles might gather in certain tissues and then scan the body with a magnetic resonance imaging (MRI) with the aim of highlighting existing illnesses.

Another group of nanodevices might be programmed to bring certain substances to cells or might be injected into the bloodstream to seek out and remove damaged cells, grow new cells, or perform other procedures. Nanosponges circulating in our bloodstream could absorb and remove toxins.

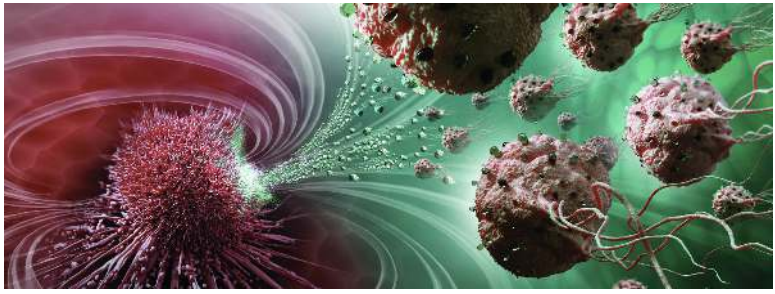
The John Hopkins University has developed robots only 1 millimeter across that can take biopsies inside the colon. Patients swallow a tiny capsule, and the robotic biopsy comes out with it. Engineers are working on having these robots perform surgery inside the colon, too.

An evil creature will use nanotechnology to control and influence people?

According to optimistic futurists, nanomedicines like smart drugs will lead to the prevention of all illnesses, even aging, making us

superhuman from many perspectives. However, as every tool in the hands of humans, nanotechnology also has downsides.

Nanobots are so tiny that it is almost impossible to discover when someone for example puts one into your glass and you swallow it. Some people are afraid that by using such tiny devices, total surveillance would become feasible – since nothing can remain hidden when there is a robot swimming through your bodily fluids. Who and how will use our information? Might there be criminals or terrorists out there who attempt to utilize these nanobots to deliver toxic or even lethal drugs to organs? Should we prepare ourselves again for a new type of terrorism?



Also, while these questions are relevant and might cause some discomfort, there are some bigger questions at stake here with even larger impact. What if there comes a point at which the overlap between nanorobots and our own cells–organic material merging with synthetic ones–becomes problematic? If nanobots can replace cell functions or even the entire cell, then what part of us remains human? What if the army of nanorobots will perfectly merge with our cells and we cannot know anymore to what extent we are humans? We already know that neurons can live in harmony with a biochip and make connections with electrodes. What happens when we and the tiny computers living inside us become one? Do we want to become one in this way?

I think the medical community and also the wider public should get

to know the particularities of nanotechnology as soon as possible to be able to prepare in time for the future. I believe that we should also start a discussion about the ethical and philosophical issues concerning nanobots. We should create groups of bioethicists who can help society assess the risks appropriately and help decision-makers to regulate the use of nanotechnology according to the common good.

Will The Medical Tricorder From Star Trek Become Real?

Analyzing disease instantly: the medical tricorder has been one of the most exciting futuristic technologies in medicine since Star Trek. But will it ever get to the black bag of General Practitioners?

As a movie fan, I love talking about how the science fiction movies of the last 100 years have shaped our ideas about medical technology. When university students doing film studies asked me to give a talk on how sci-fi influenced medical technology, I dedicated a whole section to technology inspired by Star Trek. The long list includes telepresence, the hypospray for painless injections, voice–activated communicators, the iPad, diagnostic beds that tracked numerous vital signs, and of course the famous medical tricorder.

A working tricorder

When Dr McCoy grabbed his tricorder and scanned a patient, the portable, hand–held device immediately listed vital signs, other parameters, and a diagnosis. It was the Swiss Army knife for physicians. When our class discussion turned to potential medical uses, a doubtful student asked how such a thing could work in real when it came from science fiction. I then gave him another list to consider. A visual display device from Star Trek is Google Glass now. The heads–up display in *Minority Report* is air touch technology. *Iron Man* is currently being developed by DARPA. The self–directed vacuum cleaner from *The Jetsons* now exists as *Roomba*. I could go on.

A working tricorder could bring about a new era in medicine. Instead of expensive machines and long waiting times, information would be available immediately. Physicians could scan a patient, or patients could scan themselves and receive a list of diagnostic options and suggestions. Imagine the influence it could have on underdeveloped regions. It should not substitute for medical supervision, but when there is none it comes in handy.

It could be useful when a diagnosis needs confirming or when standard laboratory equipment is not available. A high–power microscope with a smartphone, for example, could analyze swab samples and photos of skin lesions. Sensors could pick up abnormalities in DNA, or detect antibodies and specific proteins. An electronic nose, an ultrasonic probe, or almost anything we have now could be yoked to a smartphone and augment its features.

An in–person doctor visit includes assessing the patient's condition, health parameters, and other data. Much of this could be performed without needing the presence of a medical professional. I'm merely pointing out an absence of medical staff is the case in many regions of the world.

Competitions move this forward

This situation is an impetus behind the Nokia Sensing X Challenge[110] that has called for teams to design prototypes of a working tricorder. It should measure a wide range of biomarkers with a droplet of blood, be able to diagnose malaria, high blood pressure, and similar conditions, as well as monitor epilepsy. The winning finalist teams are expected to test their prototypes with thousands of users in 2015.

The Qualcomm Tricorder X Prize was announced in 2012 to motivate innovators in this direction. It featured 230 teams from thirty

[110] http://sensing.xprize.org/

countries, and promised an award of $10 million to the first team to build a working medical tricorder. The device had to correctly diagnose fifteen different medical conditions from a sore throat to sleep apnea and colon cancer.

Using these devices should also be intuitive so that anyone who understands a smartphone should be able to operate them. Consumer usability is almost as important as medical accuracy. A friendly interface will count when choosing a winner. Teams from Northern Ireland, the US, Slovenia, India, Taiwan, Canada, and the United Kingdom are working on systems that can analyze samples of blood, urine, and saliva.

I must warn that these competitions do not and cannot substitute for clinical trials. There are safety, privacy, legal, and liability issues that can only be assessed during strict trials.

The first working medical tricorder is the *Scanadu Scout*[111], a hand–held sensor held against a patient's forehead. It measures heart rate, breathing rate, blood oxygenation percentage, and body temperature. It can also take a reading of blood pressure, the electrocardiogram, and stress levels. The company is also working on Scanadu Urine for home use, which will give users data about liver, kidney, urinary tract, and metabolic functions. A smartphone app will guide users through the test procedure, processes the test results, and explain them. This is also a big potential for error or human misinterpretation.

Viatom Technology[112] in China released *CheckMe* in 2014. It measures ECG, pulse, oxygen saturation, blood pressure, body temperature, sleep quality, and daily activity. *Vitaliti* from *CloudDx* measures the same and sends data to the cloud. It lets users know about posture, physical activities and vital signs.

[111] https://www.scanadu.com/products/vitals
[112] http://www.viatomtech.com/

US researchers just announced[113] a new sensor that can be worn on the chest and tracks biochemical and electrical signals in the human body. It provides real-time data on electrocardiogram (EKG) heart signals and levels of lactate, a biochemical that helps chart physical effort.

A big part of practicing medicine today is the way to obtain vital signs. The tricorder could bypass this problem by making vital signs and even lab markers immediately available either at home, at the doctor's office, or at remote locations that lack medical supervision. Today a doctor's expertise is needed to analyze as well as collect the data. The creativity and wisdom of physicians will be hard to get replaced. But obtaining data with a device should be something a 5 year–old could perform, and only technology can bring this to us. Empathy and a patient's emotions cannot be scanned, but vital signs can be.

It is possible that the FDA or other authorities will oppose the development of such a device, or that physicians will not be happy about patients getting the chance to do a health checkup themselves. They cannot stop this, but they could regulate the industry.

The question is when we will start using medical tricorders, not whether we will use them. This is a good chance if we want people to access affordable care.

[113] http://www.upi.com/Health_News/2016/05/23/Could-Star-Trek-like-tricorder-for-health-be-near/4841464018487/

Robotics in Healthcare — Get Ready!

In the near future we will inevitably work closely with medical robots. If we take the necessary steps now to gain better understanding of how they work the transition could be easier and simpler.

While there are concerns for machines replacing people in the workforce, the benefits are tempting. Imagine how a machine that doesn't need sleep or food, doesn't have prejudices that we humans so often have could change the way we treat people who are sick and vulnerable. With some preparation and forethought, we can make sure the human touch stays relevant in medicine while taking advantage of our metallic allies. For this reason, here are some interesting examples of robotics in healthcare.

Wide range of medical robotics in healthcare

Surgical Precision

Surgery is an unpleasant experience at best. The waiting lists can be long depending on available manpower and resources. daVinci[114] helps alleviate the problem. It has been used in a wide variety of fields from head and neck to urologic surgery. The surgeon is in complete control of the system at all times, however as the machine has greater reach and flexibility, smaller incisions made with more precision are enough to access the problem areas.

[114] http://www.davincisurgery.com/

Putting the "Care" Back in Healthcare

During a hospital stay patients interact with nurses the most. They draw blood, check your vital signs, check on your condition and take care of your hygiene if needed. They are often overwhelmed[115] by physically and mentally daunting tasks, and the result is often an unpleasant experience for everyone involved. Robotic nurses will help carry this burden in the future. They are designed to be able to carry out repetitive tasks. This way the staff has more energy to deal with issues that require human decision making skills and empathy. Certain robots can even take your blood sample[116].

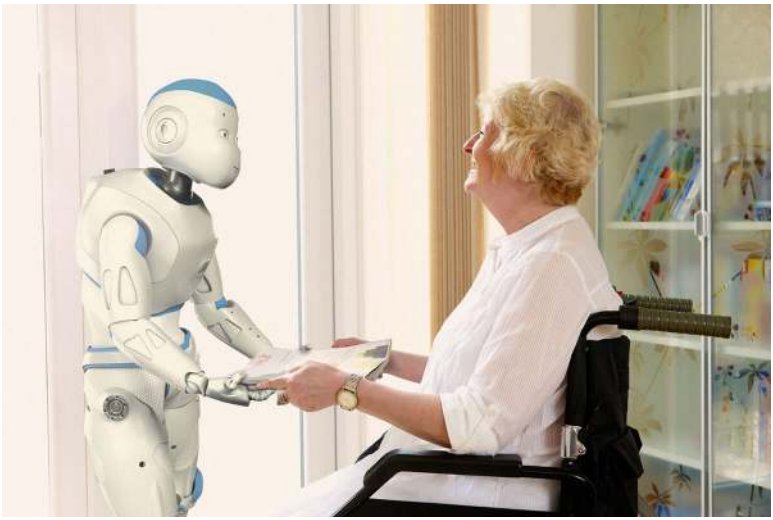
Robotic Assistance for a Better Life

But robotics in healthcare is so much more than drawing blood. With a remote controlled robot, such as the ones developed by

[115] http://asq.org/qualitynews/qnt/execute/displaySetup?newsID=19866

[116] http://medicalfuturist.com/2015/04/16/watch-a-robot-drawing-blood-from-patient/

Anybots Inc[117] caretakers can interact with their patients, check on their living conditions and the need for further appointments. This would help efficiency a great deal by eliminating the time consuming home visits. Companies producing and the ones maintaining the system will have to make great efforts to alleviate privacy concerns. As with every such device, it must be near impossible to access for non-authorized personnel. With the proper safeguards in place these robots can greatly improve the lives of caretakers and patients alike.



Telemedical Network is Key in Accessibility

Chances are you have been in a situation before where, if an accident were to happen, medical professionals would not have been able to reach you in time. To some of us in the developed world it's a rare occurrence. But even in 2016 billions live outside of the reach of conventional emergency services. With InTouch Health[118],

[117] https://en.wikipedia.org/wiki/Anybots
[118] http://www.intouchhealth.com/

patients in remote areas have access to high-quality emergency consultations for stroke, cardiovascular, and burn services. On the patient's side it can be accessed on a tablet or personal computer, and clinicians can also use the same type of devices as best suits their needs.

The Power of Exoskeletons

You have seen them in movies, taken advantage of them in video games and now they are here for real: exoskeletons. With the help of these devices paralyzed people can walk[119], rehabilitation of stroke or spinal cord injury patients. They can enhance strength in order to allow a nurse to lift an elderly patient. While they have many exciting uses, it's important to remember that currently they are costly to make and power, so at least at first they will not be available for everyone. Although, in some cases insurance companies had to cover the costs[120]. Because of this it has the potential to deepen already existing social and economic inequalities. Decision makers have to lay the groundwork to regulate the use of such devices. They will have to stay up to date on their capabilities to prevent misuse.

[119] https://www.technologyreview.com/s/546276/this-40000-robotic-exoskeleton-lets-the-paralyzed-walk/

[120] http://www.popsci.com/insurer-must-cover-exoskeleton-says-medical-review-board

Robots in the supply chain

The great thing about robots is that they can be built to be so durable that they can overtake tasks that for humans would be simply too dangerous. Take Petman[121] for example: designed for testing chemical protection clothing. It moves freely and can even adjust suit temperature and simulate sweating to provide realistic conditions.

Such solutions not only minimize the risk to human testers, in the long run mechanization of the supply chain makes production cheaper as well. Robots don't need vacations, to eat or sleep. With a new generation of them more sturdy, agile and flexible than ever they increase productivity in all kind of factories.

[121] http://www.bostondynamics.com/robot_petman.html

Disinfectant Robots in Healthcare

Hospital acquired infections (such as MRSA) are among the leading causes of death in the US. According to CDC statistics used by Xenex[122] show that in the United States, 1 in every 25 patients will contract an HAI. Of those, 1 in 9 will die. In addition to the human cost, it takes its toll financially as well. These infections cost more than $30 billion dollars a year. Xenex, a Texas based company produces a unique robot. It uses high intensity ultraviolet light[123] to disinfect any space in a healthcare facility quickly and efficiently. The Xenex Robot is more effective in causing cellular damage to microorganisms than other devices designed for disinfection. It reduces the number of hospital acquired infections. It's yet another example of how robotics in healthcare helps hospital staff to decrease workload and will lead to a much friendlier environment.

Robots come in all shapes and sizes

The origami robot[124], despite its size, is just as impressive as a super strong carrier one. When swallowed, the capsule containing it dissolves in the patient's stomach and unfolds itself. Controlled by a technician with the help of magnetic fields it can patch up wounds in the stomach lining or safely remove foreign items such as swallowed toys.

There are numerous projects in the works to develop microbots that can travel through bodily fluids to deliver medication exactly to where it's needed, or even to repair damaged cells. Though most of these are only theories today, tomorrow we very well could be fighting off infections with the help of nanobots that are built to mimic our white blood cells, only doing a much faster and effective job of destroying bacteria.

[122] http://xenex.com/

[123] http://www.xenex.com/how-uv-disinfection-works

[124] http://www.forbes.com/sites/janetwburns/2016/05/19/tiny-origami-robot-captures-intruders-patches-holes-in-stomach/#827ca632208c

Pharmabotics

As with nurses, pharmacists are burdened with tasks that could be eliminated by utilizing the advancing robotics in healthcare. Heavy lifting, as always, is a big help, but a robot could process information much faster and much more accurately than humans. This way it could make more precise recommendations after sifting through the patient's available medical data. Pharma dispensers[125] could work as an ATM does, so no matter time of day patients can get access to their prescriptions. If robots were used for such tasks, pharmacists would have the time and the incentive to participate in the social aspect of healing: educate people of preventive measures, give practical advice and therefore make sure that healthcare truly becomes caring.

[125] https://www.scriptpro.com/products/robotic-prescription-dispensing-systems/

Companion Robots

Certain robot companions can serve as a social partner in order to alleviate loneliness or treat mental health issues. Jibo[126], Pepper[127], Paro[128] and Buddy[129] are all existing examples. Some of them even have touch sensors, cameras and microphones, thus their owners can get into discussions with them, ask them to find a great concert for that night or just remind them about their medications.

Mainstream media have a huge responsibility here. If they fail to report the amazing advantages and results[130], but they do report massively the failures such as the one[131] that said it wanted to destroy humanity (which was only a minor gap in its communication algorithm), people will think robots are coming to take our lives.

Change is often scary, and robotics in healthcare is a big one. It has the potential to do so much good: to bring medical care to regions where even today there is none to be found; to make the

[126] https://www.jibo.com/
[127] https://www.ald.softbankrobotics.com/en/cool-robots/pepper
[128] http://www.parorobots.com/
[129] http://www.bluefrogrobotics.com/en/home/
[130] http://medicalfuturist.com/2016/06/29/9-exciting-medical-robot-facts/
[131] https://www.youtube.com/watch?v=W0_DPi0PmF0

production and distribution of pharmaceuticals cheaper and more efficient; to lighten the load of medical professionals; to help people walk again. To reap the benefits and avoid the potential dangers of such a technological revolution we need to keep informed about the strides that science makes so that we can better prepare and adapt to the not-so-distant future where robots play a crucial role and work closely with us.