HEALTHCARE ENABLERS 2017

Technological developments in Western healthcare

Philip J. Idenburg and Vivian Dekkers

"The day before something is
truly a breakthrough,
it's a crazy idea."
(Peter Diamandis)
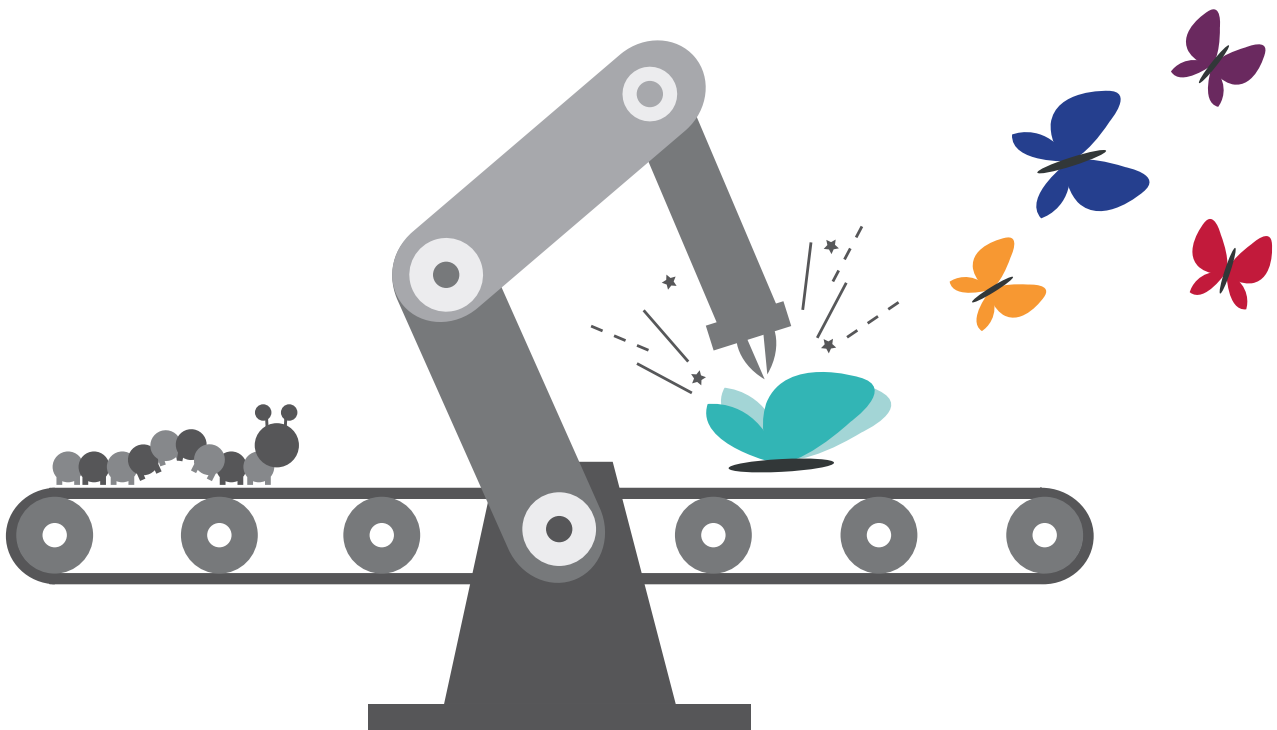
Preface

All of us deal with healthcare at some point in our life. Either while looking after children or parents, or because of our own ailments and limitations. Our relationship with healthcare is perhaps even more intense. We collaborate with healthcare providers, professionals, insurers and innovators in healthcare on a daily basis in order to maintain the quality, accessibility and affordability of the internationally renowned Dutch healthcare system. We speak of maintaining, because the rising demand for healthcare and the economic reality force us to provide even better quality healthcare for the same price, now and in the future. The sustainability of our current healthcare system is under pressure and a transformation is necessary.

This transformation requires more than just technology, but technology is an important enabler. Technological solutions allow, for example, professionals to work in a different way and make it possible to increase self-care among patients. There are numerous possibilities. Choosing the right solutions is the job of busy healthcare professionals and administrators. Wrong choices lead to accumulation and thus increased costs, while delays in making choices can result in stagnation. Therefore there is a perception that technology can result in higher healthcare spending instead of being an instrument for innovation.

We closely monitor important trends and developments in the healthcare sector. This started in 2012 with the program 'Diagnosis Healthcare Innovation'. Since then, we have further enriched our knowledge in several ways. Together with our strategic partners KPN, Noaber, PinkRoccade and Promedico we are including these technological developments as *enablers of change* in our current programme 'Diagnosis Transformation'. Over the years, a large database has emerged that contains examples of futuristic technology across many disciplines.

Until now, we have used this knowledge and the practical examples to help our clients, conduct market research, and develop new products. With Healthcare Enablers 2017 we are giving everyone insight into the considerable technological developments. To inspire those around us and to make collaboration with stakeholders more efficient in order to further improve the quality of healthcare in terms of medical outcomes and patient experience.

We describe promising technologies that are knocking on the door and that will change our healthcare in years to come. Some are about to be broadly implemented; others are still being developed.
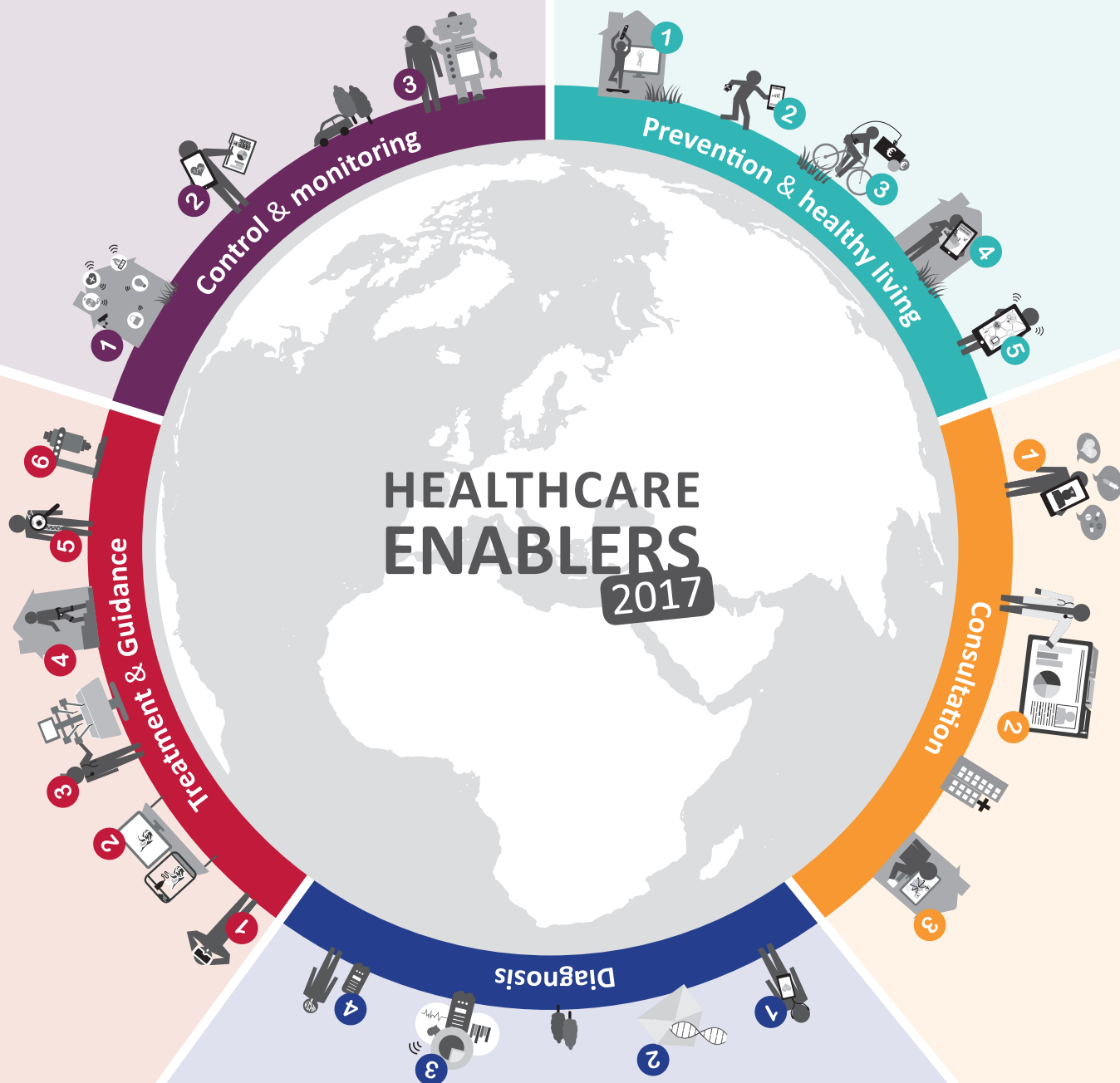
We believe that a clear picture of all technological developments is an essential ingredient for an innovative healthcare sector and innovative healthcare organizations.

With this overview we hope to inspire you and to help you determine which technologies are worth focusing on. Because of the rapid developments, we will provide annual updates. This is one of the ways in which we want to contribute to the enhancement of the innovation capability and thus the transformation of healthcare.

We did not put this content together by ourselves. In particular, we'd like to thank Sjoerd Emonts, who collected a lot of the data, conducted much of the research and laid the foundation for the end result. Monique Philippens, programme manager of 'Diagnosis Transformation', also made invaluable contributions based on her knowledge of healthcare technology and innovation. In addition, our colleagues Michèle, Arjo, Daniël, Karin, Catja, Lisa, Bo and Romy inspired us with their contributions to content, style and visuals.

We hope that Healthcare Enablers 2017 will help you strengthen the innovation capability of your organization. Only then can we together reap the benefits of new technologies and work on a sustainable healthcare system in which quality and efficiency go hand in hand. We are looking forward to further discussions about the way in which new innovations will shape the future and invite you to share your inspiration, examples and experiences with us
www.diagnoseprogrammas.nl/en/healthcare-enablers

Philip J. Idenburg and Vivian Dekkers

HEALTHCARE ENABLERS 2017

Control & monitoring

Prevention & healthy living

Consultation

Diagnosis

Treatment & Guidance

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Introduction
Technology as an enabler for the transformation of healthcare

Our society is changing. Trends and developments – such as an ageing population, the rise of chronic disease, personalized healthcare, the empowered patient and digitalization – are changing and increasing the demand for healthcare. As a result, the healthcare costs in Western countries are on the rise.

The quality, accessibility and affordability of healthcare are under pressure. Therefore, it is necessary to take a fresh look at health and the way in which healthcare is organized. Small adaptations are no longer sufficient; a transformation is required. Technological innovations can contribute to this.

Western healthcare has proven to be very successful. The technological possibilities for curing, treating and preventing disease have grown tremendously over the last decades. Illnesses that were previously considered terminal can now be cured or have become a chronic disease. Due to digitalization, better access to research data, and intensified research more new products, services and treatment methods are becoming available all the time. Many technological solutions provide the building blocks to help make the transformation of healthcare a reality. These solutions focus on healthcare that is personal, participative, preventive and predictive.

The big question healthcare professionals and administrators often struggle with is which technology to adopt and when. The supply is overwhelming and covers a broad range of technological disciplines and applications. Which technologies truly contribute to the quality, accessibility and affordability of healthcare? And how do we weigh up better quality and the financial consequences of a new technology, i.e. financial investment and healthcare costs?

In Healthcare Enablers 2017 we bring together the most important technological trends and developments. These are technologies that will take their place in the various phases of the healthcare process. From pre-care and diagnostics to treatment and aftercare, in preventive, curative and long-term care. We have classified the technologies according to the phases of healthcare that make up the HealthValueCycle, as described in Diagnosis Healthcare Innovation in 2013[1].

In the HealthValueCycle the central focus is on the individual and the healthcare process has a cyclical character. The main principle is the quality of life of the individual, in which vitality and wellbeing are the two most important elements. 'Being healthy' is no longer defined as the absence of disease, but as 'the ability to adapt and make your own choices in the context of social, physical and emotional challenges in life'[2].

The five phases of healthcare are:
1 Prevention & Healthy living
2 Consultation
3 Diagnosis
4 Treatment & Guidance
5 Control & Monitoring

For each phase we describe a number of important technological developments and give practical examples. Most of the technologies can be applied in multiple phases of healthcare and will affect everyone involved in the healthcare system.

This overview is not exhaustive. However, we expect that the technologies we mention will be the ones influencing the future of healthcare and contribute to the quality of healthcare, in terms of medical outcome and patient experience. Through co-creation with those patients/clients and healthcare professionals, organizations have to make the right choices and set the right priorities without losing sight of the financial costs.

Aging population

0   65+

To a holistic concept of man

More chronic diseases

Increasing costs

Personal

Preventive

DISEASE MANAGEMENT

HEALTHCARE TRANSFORMATION

HEALTH MANAGEMENT

ICT and eHealth

Pharma and biotechnologies

Medical technologies

Consumer market developments

Nutritech

1 2 3 4

Participative

Predictive

SOLUTIONS FOR CHANGE

© BeBright 2015

ENABLERS OF CHANGE

10 needs for change

CHANGING SOCIETY
An ageing population, a growing number of people with chronic diseases, and more ethnicities change society.

2015   2030

MORE HEALTHCARE, GREATER COSTS
Annual healthcare costs rise; this is true for both total costs and costs per person, which increase with age.

FEWER HEALTHCARE PROFESSIONALS
Healthcare staff shortages emerge.

POWER-TO-THE-PATIENT
Patients increasingly make their own decisions; self-management and patient choice become increasingly important.

CONNECTIVITY
Care is becoming digitalized and the connectivity of and between patient and healthcare professional is growing.

WORLDWIDE KNOWLEDGE
Globalization is reshaping society and (medical) information is shared faster and more easily.

Google

PERSONAL HEALTHCARE
Everyone is different and healthcare and treatment become increasingly personalized.

QUALITY AND TRANSPARENCY
People demand quality and transparency; healthcare attracts more media attention and the quality of healthcare organizations is reviewed more often.

DECENTRALIZATION
Non-specialist healthcare moves closer to home and is increasingly provided in an integral way.

PREVENTION
The focus shifts from 'disease and healthcare 'to 'health and behaviour'.

Prevention & Healthy living

The aim of PREVENTION is to ensure that people stay healthy. It has a universal approach: improving and protecting health. But it can also be selective, deemed necessary, or disease-related: preventing illness and complications or detecting them early. Prevention is associated with health promotion initiatives by the government, employers, educational institutions or healthcare organizations.

HEALTHY LIVING refers to an individual's own behaviour and responsibilities. The most important motivation for starting to live a healthier life depends on the confrontation of an individual with him or herself. Facts about a person's own health serve as a mirror.

Within this phase of healthcare, we identify five great technological trends that contribute to a greater or lesser extent to prevention and healthy living:

1 **Serious Gaming**
2 **Holistic Tracking**
3 **Incentivized Wellness**
4 **Smartfood**
5 **Internet of Things**

Serious gaming

> ## Playing a game is the voluntary effort to overcome unnecessary obstacles.
>
> (Bernard Suits)

Serious games are games that are not primarily designed for the purpose of entertainment but for the purpose of education, training or behavioural change. Serious games come in many forms: it can be a 'paper-based' board game or card game, a facilitated management game or a computer game. The entertainment aspect of a serious game helps to heighten the experience and therefore the transfer of information[1].

Serious games are used in healthcare to improve general health, for example. They motivate people to adapt their lifestyle habits and stimulate positive behavioural change, while also allowing self-management and promoting and supporting physical activity[2]. The variation in game elements ensures that players become and stay intrinsically motivated to overcome challenges and hurdles. Visualizing change and progress helps to improve the self-efficacy. Sharing knowledge, setting goals and facilitating communication and interaction among patients and other people improve the chances of successfully overcoming a challenge[3]. In areas such as mental health and addiction care, it has already been proven that the use of serious games can deliver results[4].

The following four goals can be distinguished:

- **EDUCATION** 'E-learning: the use of electronic media and ICT in education'. Games can help healthcare professionals to practice operations and situations, and patients to learn more about their illness and how to cope with it in daily life.
- **EXERCISE** Games that combine gaming and physical activity in the 'exergaming' category. These games promote an active lifestyle.
- **INTERACTION** Some games are developed to promote interaction among players, elderly people or children, for example.
- **TREATMENT** Integrated games in treatment and aftercare help patients with motivation and therapy adherence.

Re-Mission 2 is a collection of 6 free online games in which cancer patients battle against various virtual cancer cells with an arsenal of weapons and super powers such as chemotherapy, antibiotics and the body's natural defences. Re-Mission 2 has been on the market for a while.

Research has confirmed that the rewards players receive for destroying cancer cells lead to positive associations and emotions with chemotherapy and antibiotic treatments, while treatment adherence improved too.

www.re-mission2.org

Qwiek ®
"Zorginnovaties met beleving"

Qwiek.up can provide clients with various levels of stimulation via an audio-visual experience in their own environment. Its experience modules bring a variety of different experiences to the care home. The Fit & Vital modules encourage clients to become more physically active; from dancing to music to challenging games. The modules are designed to engage clients with what they see projected on a wall, in combination with proper guidance and fitting music.

www.qwiek.eu

Value of the global serious gaming market 2015-2020

5.4bn (2020)

2.5bn (2015)

2015   2020

The value of the global serious gaming market is expected to reach 5.4 billion USD by 2020, at a compound annual growth rate of 16.4% from 2015 onwards[5].

TOUCHSURGERY

Touch Surgery is a free mobile application that simulates surgical procedures in 3D on virtual patients. In every procedure, users have to interactively perform several tasks. Thus surgeons are trained in performing and understanding surgical tasks in a very accessible manner. Moreover, scores are calculated and can be compared to top scores and average scores. More simulated surgical procedures are added to the application each year. In August 2016, there were more than 70 procedures.
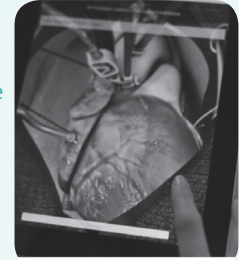
www.touchsurgery.com

The serious gaming industry has become a multi-billion industry and is still booming[5].

The total market value will continue to grow until 2020[5]. Several factors are driving this growth[2,3,5,7]:

- The falling cost of technology increases the accessibility of serious games. In addition, more and more people have a smartphone or another high-end device. In combination with increased network connectivity, it is possible for manufacturers to develop serious games for a growing number of people.
- Serious games fulfil an increasingly important role in promoting behavioural change. They make it fun and entertaining for people of all ages to take on challenges. In addition, serious games are showing the potential to simulate scenarios that can help anyone, from healthcare professional to patient. As social games, they even kindle collective efforts to promote health.
- As more companies are developing games, more specific hardware and software is becoming available. This offers various conditional, sensory, motoric and cognitive possibilities.
- Serious games make it possible for individuals to participate in research studies.

Despite the strong growth of the gaming industry, the use of serious games in healthcare is still limited, because serious gaming comes with its own challenges. The greatest challenge is how to measure its impact. The healthcare system uses evidence-based ways of working and proving the impact of a serious game is not always easy[1,2,8]. Unsuitable game design, image, and lack of awareness among potential users hamper application[1,6]. Healthcare professionals and behavioural scientists together with game designers and developers can speed up the development of serious games and their application to healthcare[2]. Then serious gaming can make healthy living fun and contribute to better healthcare.

Holistic tracking

> ## "I am prescribing a lot more applications than medications these days.

(Dr. Eric Topol)

⭐ *Holistic tracking* is a trend that integrates technology in daily life in order to collect information about personal health. Examples are biometric data, physical as well as mental, about performance, mood and vital signs.

📦 With the help of (mobile) applications and wearables users can monitor what they do and how it affects their health. Monitoring personal health encourages a healthy lifestyle as it creates awareness and the ability to make informed choices. It enables individuals to 'manage' their health[1]. Holistic tracking is a type of self-tracking, one leads to *the Quantified Self*, a term coined in 2007 by Garry Wolf and Kevin Kelly[2]. *The Quantified Self* is a trend that focuses on the phenomenon that humans are increasingly integrating technology into their lives in order to collect data about themselves and to learn from this[2].

📌 The holistic tracking industry is experiencing explosive growth. IDC expects 18% growth in 2016 compared to 2015, leading to a total of 110 million wearables dispatched in 2016. It is estimated that this total will reach 237 million by the end of 2020[3]. In 2020, smartwatches will make up a third of this total, compared to a quarter in 2016[3]. Especially the smartclothing, eyewear and hearables segment is set to grow[3]. In addition, in the near future wearables will be implanted under the skin: implantables[4]. It is striking that one in ten consumers in Western Europe who purchase a smartphone also buys a wearable[5]. A recent study under Americans showed that 31% of the participants were positive about the use of wearables to monitor vital signs. No less than 85% of healthcare professionals imagine that in the future they will rely more on health apps and wearables[6].

Fitbit is one of the best-known wearables suppliers in the world. The Fitbit Charge 2 is a combination of smartwatch and activity tracker, equipped with sensors to track your steps and monitor your sleep, among other things. In addition, the wristband contains software that is capable of estimating your heart rate and VO2-max 24/7 and automatically recognizing certain activities. All of this data is synchronized with the Fitbit app so it can be read out easily. This enables the user to monitor his own health and possibly adapt his lifestyle.

www.fitbit.com

My UV Patch

My UV Patch is a transparent adhesive with stretchable electronics that can be directly applied to any area of the skin. The patch contains photosensitive dyes that change colour when exposed to UV rays to indicate various levels of sun exposure. The UV Patch can be scanned by an app that will then report your personal UV exposure. It takes into account your skin type, your use of sunscreen and the UV index at your location. This enables users to make safe choices in the sunshine.

www.laroche-posay.us

**Value of the global
health app market 2013-2018**

20.7bn

6.3bn

2013   **2018**
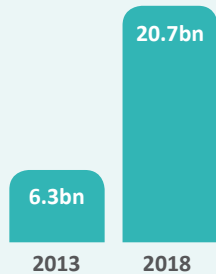
The value of the global health app industry market is expected to reach 21 billion USD by 2018, at a compound annual growth rate of 26.7% from 2013 onwards[3].

Calm

Calm is a health app that offers its users meditation exercises to help them improve their health, performance and quality of life. The app keeps track of progress and personal sessions and responds to your inner peace. Calm helps you to lower your stress levels, improve your sleep, and lead a healthier and happier life.

www.calm.com

Learn the life-changing skill of meditation

In 2015, there were more than 165,000 iOS and Android health apps available. For iOS alone there was a 106% increase compared to 2013[7]. The value of the global health apps market will continue to grow between 2013 and 2018[3]. Recent research by PwC has shown that in 2015, 32% of Americans had at least one health app on their smartphone, compared to 16% in 2013[8]. Almost 90% of the wearables feature wireless synchronization with an app and more than half are designed to wear on the wrist[7]. The largest proportion of health apps is made up of fitness apps (36%), followed by lifestyle and stress apps (17%) and diet and food apps (12%)[7]. The Future Health Index (FHI) showed that there is a clear generation gap among holistic tracking users[8].
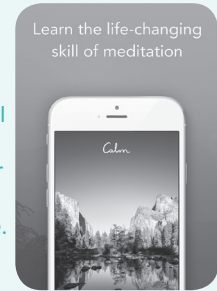
The rise of health apps can be attributed to the following factors[3,9]:

- More and more people have a smartphone or another high-end device, combined with increased network connectivity (e.g. Bluetooth, Wi-Fi, and the introduction of 3G and 4G networks), while the rising healthcare costs call for affordable solutions.
- There is greater awareness among people of the possibilities to manage their own lifestyle. Society is placing more importance on health and healthy lifestyles. With increased focus on personalized medicine, society is searching for new technological innovations to achieve this.
- Progress in technology drives the market. It has become much easier to develop a mobile application, for example.

Despite the rise of holistic tracking, some great challenges hampering widespread application remain. Many people protect their privacy out of fear that personal data can fall into the wrong hands[7,10]. Moreover, many healthcare professionals don't have access to IT infrastructure that allows them to link patient generated data to their own information and to open this up at work[7,11]. When personal data can't be digitally shared with healthcare professionals, many users regard the technology as less valuable[12]. In addition, there is a risk that all this monitoring will generate too much information. Too much and contradictory data will confuse consumers rather than give them greater insight into their own health[12,13]. In addition, the newly acquired data can result in greater healthcare consumption, which will put added pressure on the healthcare system[14]. Finally, stringent legislation and regulations, conservative healthcare professionals, and findability of technology hamper further application of holistic tracking in healthcare[3,7,12].

In the future, however, our ability to measure and monitor our health will increase. First of all, because technologies will enable us to do so, and, secondly, because they will become more integrated in everyday items, such as mobile phones and watches. With a growing number of patients with chronic diseases and a focus on health promotion, the ability of the healthcare system to collect data and to make it accessible to both patients and healthcare professionals should grow, so that this information can be used in the healthcare process.

Incentivized wellness

> ❝ **Sooner or later,
> we sell out for money** ❞
> (Tony Randall)

Incentivized wellness, or promoting health with rewards, is a technique that is used to motivate people to make healthier lifestyle choices and improve their behaviour by offering emotional or financial rewards. It is a type of prevention that attempts to prevent people from becoming ill. For example, through a healthier diet, more physical activity or giving up smoking.

Rewarding people really works, as described by Victor Vroom in 1964 in his expectancy theory, which was redefined by Porter and Lawler in 1968[1]. His theory drew a connection between motivation, performance and reward. Reward strategies are often used in other sectors, such as the mobile applications industry[2]. Users receive a reward for behaviour such as downloading another app, watching a video or frequently using the app. The rewards often consist of virtual currency, game items, an upgrade or discount for a particular product or service.

As a healthy lifestyle is associated with better health[3], the benefits of incentivized wellness should be clear. In addition to a healthier lifestyle, the person receives a reward (emotional or financial). Ultimately, incentivized wellness can result in lower healthcare costs[4].

Sweatcoin

Sweatcoin is an application that converts physical activity into money. Via GPS and accelerometers your smartphone tracks the number of steps that you take. One thousand steps are worth about one Sweatcoin. The app lets users spend these coins on real products, services and experiences, such as charities, yoga lessons and sports gear. By rewarding achievements in this way, Sweatcoin attempts to create a physically active society.

www.sweatco.in
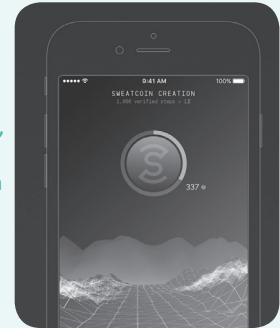
Fitbit Adventures offers an application that encourages users to take on challenges in a personal and non-competitive way. The app allows users to embark on two virtual adventures, during which they can discover landmarks, collect treasures, and earn badges by taking a certain number of steps per day. A new goal is set each day, based on the historical and personalised data stored in the app. When goals are achieved, the number of steps to be taken the next day increases. Fitbit Adventures inspires and motivates users to increase their exercise, to achieve health and fitness goals, and takes you to places you would otherwise never visit.

www.fitbit.com
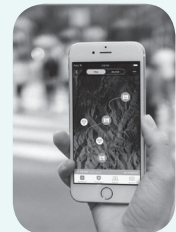
Statement: 'Mobile stimuli drive me to take action'

25%
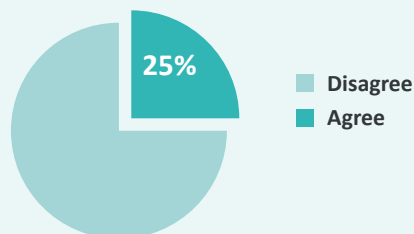
- Disagree
- Agree

Recent research revealed that 25% of 25 to 44-year-olds agree with the statement that mobile stimuli drive them to take action. They recognize the benefits of personal, transparent and direct data[12].

DietBet

DietBet offers users an incentive to lose weight. Users can bet a sum of money via DietBet on losing x percent of their bodyweight within a certain time period. This money is added to the jackpot. When the time period has ended, the jackpot is shared among all participants who have reached their goal. Users can interactively share their progress with other participants. Thus DietBet helps users make a concrete commitment to creating a healthier lifestyle.

www.dietbet.com

Developments in incentivized wellness are taking place at various levels. Health insurers reward clients by charging lower premiums if they live a healthy lifestyle[5-7]. In the interest of business continuity, 'healthy employees' are becoming more important to employers. They set up health programmes that reward employees for having a healthy lifestyle[4,8]. In the United States, employers are encouraged to make progress in this area via the Affordable Care Act (ACA)[9]. One way in which they do this is by investing in wearables and apps to track employees. When there are (financial) rewards for healthy living, the participation in health programmes increases by 60%[10]. These investments lead to a healthier workforce, which in turn results in fewer visits to the doctor and lower medical costs due to illnes[10].

The rise of mobile health applications that inform, educate and motivate users also drives the growing impact of incentivized wellness[11]. More and more people have a smartphone and there is a growing awareness of the importance of a healthy lifestyle. Due to improved and renewed designs more and more people apply this to their daily lives.

Although many people are aware that they need to change their lifestyle, research shows that there are several barriers that prevent lasting lifestyle changes.

These are both aversion of 'have-to's' and dreading the necessary changes[12]. Incentivized wellness can break down such barriers. However, the question is whether it is better to reward a healthy lifestyle or to punish unhealthy behaviour? An example of a 'punishment' could be withholding a reward or using a financial incentive, as some American employers do[9,13]. Research shows that when it comes to behavioural change, people tend to be more responsive to negative incentives than to positive ones, which makes punishment a more effective way to promote a healthy lifestyle.

There are still many questions to be answered about the effective-ness of incentivized wellness[9]. Much of this is due to the design of the interventions and experiments with this instrument. It is important that both the reward and the activity that contribute to behavioural change suit the user[9,11]. On which behaviour lies the focus? Which reward or punishment is used? And when is this reward earned or punishment given?

Healthcare is going through a transformation from 'disease and healthcare' to 'health and behaviour'. Incentivized wellness applications fit in this shift and are expected to accelerate and make positive contributions to this transformation.

Smartfood

"Everything in food is science. The only subjective part is when you eat it"

(Alton Brown)

Healthy food and its impact on health is a topic that more and more people are concerned about. People are more careful about what they eat and research into the relationship between food and health is expanding. We are becoming better informed about which foods have a negative effect on our health. In 2015, the Health Council of the Netherlands published new guidelines regarding food consumption[1]. This is becoming more important as there is a growing global trend of food-related health problems.

The growing global trend of food-related health problems.

Worldwide there are 220-250 million people who suffer from a food allergy. The incidence is greater in children (5-8%) than in adults (1-2%)[2] and the numbers are increasing[3]. Every three minutes someone in the United States is admitted to A&E department because of a food allergy. Together they amount to 200,000 emergencies per year: an enormous expense to the healthcare system[4].

Worldwide, the prevalence of obesity grew by almost 4% over the period 2010-2013 and has more than doubled since 1980[5,6]. In 2014, 39% of adults were overweight, 13% of which even had a BMI of more than 30[6].

It is expected that in 2040 more than 600 million people worldwide will have diabetes. An expected increase of no less than 54% compared to 2015[7].

tellspec
Beam your health up

The Tellspec Food Sensor is a scanner that uses spectroscopy to scan food and identify its contents at molecular level. This data is automatically linked to the Tellspec app that can quickly show you the ingredients on your smartphone.

The Tellspecopedia, an online database, provides users with extra information about these nutrients. Thus the Tellspecopedia can inform users about specific ingredients, allergens, calories and macronutrients in the food product and whether it is bad for your health.

www.tellspec.com

HAPIfork

The HAPIfork is an electronic fork that helps users monitor and track their eating habits. It measures the amount of fork servings or number of times the fork is brought from plate to mouth. The HAPIfork also measures how long it takes to eat your meal, the amount of fork servings taken per minute, and the intervals between fork servings. All this information is then uploaded to the HAPI app on your smartphone. Thus HAPIfork monitors and tracks users' eating habits and can recommend to eat more slowly if necessary.

www.hapi.com

A healthy diet contributes to a person's wellbeing. Knowledge of what we eat and of the relationship between food and health underpins the choices made in the search for a healthy diet. This is an area in which many technological innovations are being introduced, such as food scanners, nutraceuticals, food biotechnology and 3D printing of personalized food (see also 'Printing procedures'). In 2016, the European Commission launched the Horizon Prize for a food scanner. In this competition, participants develop prototypes of affordable and non-invasive mobile solutions that allow users to measure and analyse their food intake[8]. *Smartfood* enables consumers to gain more insight into the ingredients and amount of calories their food contains, and into the presence of allergenic or toxic substances. Meals or specific foods can be enriched (in a personalized manner) with health promoting components in order to help battle chronic diseases such as cancer and diabetes.

Projections for the future of smartfood applications are difficult to make, because they are still at an early development stage. But there are some numbers available. The value of the global food bio-technology market is expected to reach $2.17 billion by 2022, with a compound annual growth rate of 8.1% over the years 2015-2022[9]. The value of the global nutraceuticals market is expected to reach almost $279 billion in 2021, compared to $165 billion in 2014[10].

In addition to an ageing population and a rising number of people with chronic diseases[11], several other factors are driving the growth in the smartfood market:

- Consumers are more aware of what the human body needs and the negative effects of certain nutrients. Food must not only fill the stomach, but also be healthy and tasty and improve (physical) performance[10,12-14]. The rise of holistic tracking supports this trend and makes it easier for consumers to gain insight into their own health and further dietary interventions, if desired.
- Increasingly stringent regulations regarding ingredients such as salt, sugar, fat, and added food dyes and conservatives in products and a rise in food-related illnesses call for innovative and technological solutions[11,13].
- Nutritional genomics is revolutionizing the field food and health[15,16] and can be subdivided in nutrigenomics and nutrigenetics[17]. Nutrigenomics is a research area that focuses on how nutrients and diet influence gene expression and thus a person's risk of disease. Nutrigenetics focuses on the role genetic variations play in the interaction between diet and illness[17]. These research areas will lead to personalized nutrition.

Lose It!

Lose It! is a free smartphone application that helps users lose weight in a healthy manner, and maintain a healthy weight. Lose It! recently introduced a new feature for the app: Snap It!. With this feature users simply take a picture of their meal, after which Snap It! analyses the meal and indicates how many calories it contains. This also allows users to keep a food diary.

www.loseit.com

Because of issues such as the rise of diseases of affluence in society, a strong growth in smartfood is expected. However there are barriers that must be overcome. The application of this technology is very new and the sensitivity and specificity of smartfood tech-nologies needs to improve, for example[15]. The cost and lack of knowledge among consumers about the possibilities of smartfood technologies are hampering growth[10]. Moreover legislation and regulations are making it tough for smartfood to enter each market[11]. Society is still divided on the issues of food biotechnology and genetically modified food because of safety concerns, regulation, and environmental impact. Some countries even prohibit importing or growing genetically modified food[18,19].

Smartfood technology is still in its early stages. Although concrete predictions cannot be backed up yet, it is clear that in the future it will play a large role in the lifestyle of consumers.

Internet of Things

> **Everything that can be automated will be automated**
>
> (Robert Cannon)

All 'things' that exchange data among each other are jointly called the *Internet of Things* (IoT)[1]. It is not a technology in itself, but a collective name for a network of 'smart' devices such as jewellery, machines, thermostats, lights, and much more. The IoT facilitates machine-to-human and machine-to-machine communication and offers widespread possibilities for remote communication. IoT provides opportunities for the healthcare sector, for example through identification and detection[2]. From simple activity trackers, smart weighing scales, blood pressure sensors, pacemakers, and home devices to social networks: they will be part of healthcare in the future. Thus IoT infrastructure supports monitoring, coaching, therapy adherence, and many other healthcare processes[3].

The IoT will make it possible to collect and analyse health data more quickly and accurately. This will lead to new insights, and patient outcomes can also be improved. It also provides opportunities for elderly people to stay in their own home for longer and it will help to reduce the sharp rise in healthcare costs by providing real-time data, and to cope with the healthcare staff shortages[4,5]. The overall patient experience of healthcare can be optimized and errors can be minimized[5].

The IoT market is growing. IDC predicts that the value of the global IoT market will continue to grow until 2020[6]. While there were 'only' 8.7 billion connected devices worldwide in 2012, it is expected that there will be more than 50 billion by 2020[7]. Connected devices are primarily owned by consumers[8]. In healthcare alone, a compound annual growth rate of 38% is expected until 2020[9].

oticon
PEOPLE FIRST

Oticon OpnTM is the first hearing aid that is connected to the Internet of Things. Oticon OpnTM does this via the If This Then That (IFTTT) platform. This allows users to connect their hearing aid to other IFTTT connected devices. Oticon OpnTM can be connected to a doorbell, a TV or a baby monitor. The possibilities will grow when more IFTTT connected products become available.

www.oticon.com

amazon echo

The Amazon Echo is a smart, interactive speaker that users can control with their voice. The speaker can connect with other devices in the home, which enables users to also easily control, for example, lights, the TV and the alarm system. It can also answer questions, read audiobooks, and give weather reports, among other things. Thus the Amazon Echo provides full comfort and, for example, the opportunity for elderly people to stay in their own home for longer.

www.amazon.com

Value of the global Internet of Things in healthcare market 2015-2020

32.4bn
2015

163.2bn
2020
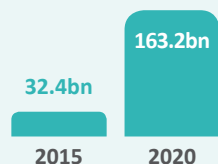
The value of the Internet of Things in healthcare market is expected to reach 163 billion USD by 2020, at a compound annual growth rate of 38.1% from 2015 onwards[9].

Factors driving the growth of the IoT within healthcare are:

- Connectivity is growing because of the development of evermore 'smart' devices such as an improved connectivity due to Bluetooth, Wi-Fi, and the introduction of 3G and 4G networks that can provide stable services. The internet has become more accessible[10]. In addition, more and more consumers own (wireless) 'smart' devices, partly due to the falling cost of technology[11,12].
- There is a growing shortage of healthcare staff, which puts added pressure on both employees and the quality, affordability and accessibility of healthcare[10,12 13]. An ageing population and rise in the number of people with chronic diseases will further increase the demand for healthcare and the pressure[14-16].
- Technological developments such as big data and cloud computing drive the market for the IoT[11,12,16]. Moreover, the sensors are getting smaller and smaller, shifting in size from millimetres to nanometres. Soon, there may no longer be an IoT but an Internet of Nano Things (IoNT). A network that will push healthcare and other sectors to the next level[17].

The IoT has great potential. However, for optimal use of the IoT several hurdles still need to be taken. The greatest challenge lies in the ability to provide user security and privacy[2,16,18-20]. The IoT operates in a complex network, in which more and more devices, processes and people communicate with each other. This makes security tricky because the entire chain needs to comply with the same requirements for confidentiality, integrity and availability. A recent report by McAfee showed that hospitals are increasingly targeted in cyber attacks because of the rising value of medical data[21]. Moreover, there is a lack of standards, and laws and regulations are hampering the growth and use of the IoT[9,18,20].

nest

The Nest Learning Thermostat is a smart thermostat that automatically adapts to the user's living environment. After just one week, it recognizes the user's behavioural patterns and programs itself to create optimal living conditions. This enhances the user's wellbeing and also helps to save energy.

www.nest.com

An inadequate digital infrastructure can also hamper the use of the IoT in healthcare. Given that the amount of available health data will grow exponentially, spending on IT infrastructure for healthcare will have to increase too, and investments will be required[5,9,20].

In addition to technological obstacles, social factors may also throw up challenges for the implementation. Some users may like to stay healthy in the short-term by using sensors in the home, for example, but may have problems changing lifestyle patterns in the long-term even though the IoT provides opportunities to do this. Integrating the IoT with serious gaming may offer a solution[22].

Clearly, the IoT will change healthcare through the interaction between people and machines. Analysing medical outcomes and realizing solutions will have to be completely redefined. The IoT provides opportunities to warrant the quality, affordability and accessibility of healthcare and will help people to live longer, healthier, and independently for longer despite health limitations.

Consultation

CONSULTATION is an integral part of almost every interaction between a healthcare professional and healthcare user in the healthcare process, but also between the healthcare user and other healthcare users. A consultation gives healthcare users the opportunity to ask for advice and discuss subsequent steps.

A consultation can lead to a diagnosis, the prescription for treatment, or the decision to refrain from treatment. The position of the individual in the consultation process is changing. Technological developments are strongly influencing this change.

Within this phase of healthcare, the following three technological trends are identified:

1 **Remote consultation**
2 **Health information systems**
3 **Online social networking**

Remote Consultation

> **The innovation that telemedicine promises is not just doing the same thing remotely, but awakening us to the many things that we thought required face-to-face contact but actually do not**
>
> (Dr. David Asch)

Remote consultation, also known as video consultation or teleconsults, is about adding an extra (visual) dimension to the usual means of communication. It offers healthcare professionals and patients the opportunity for remote healthcare. It increases communication options, and can improve contact between healthcare provider-patient, patient-patient and between healthcare professionals and their colleagues. Remote consultation will in certain cases replace direct and personal contact[1].

Remote consultation has various benefits. It saves money and (travel)time and conversations are more to-the-point[2,3]. A consultation does no longer rely on geographical proximity or time, and offers flexibility[2,3]. By bridging distances, it also provides opportunities for the provision of healthcare in remote or difficult to reach places, and for elderly people who may be able to stay in their own home for longer. It also bridges knowledge gaps by bringing healthcare professionals in contact with each other[3,4]. Remote consultation offers opportunities for informal, primary, secondary and tertiary care, such as paramedical care, a visit to a GP or medical specialist, home care, tele-ICU and multidisciplinary coordinated care[2]. There are several ways in which remote consultation can take place, namely via[5]:

- Video
- Telephone
- E-mail
- Text messages
- Mobile applications

BeterDichtbij

The free service BeterDichtbij ('better nearby') allows patients of several hospitals to ask their own hospital or physician questions, and to receive results via their phone by using a secure and user-friendly app. In 2017, more regional hospitals will be added and the number of features will increase in collaboration with several parties. Thus users can find the information that they need at any time of the day.

*www.beterdichtbij.nl*
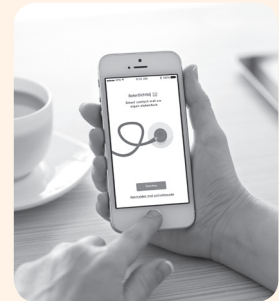
GPDQ

GPDQ allows users to book a GP visit at a location that is convenient to them. Via an app, users can request a GP for a 25-minute consultation, at home, at work, or at another location. They can also track the GP and receive live updates on his or her arrival time. GPDQ puts users in control of their healthcare and eliminates travel and waiting times.

www.gpdq.co.uk
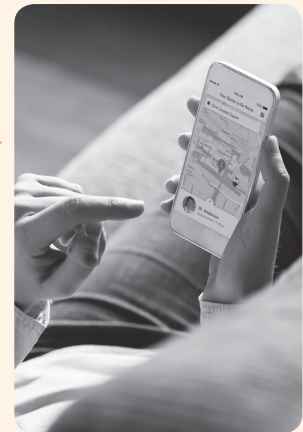
**Value of the global
remote consultation market 2016-2021**

66.6bn

23.2bn

2016   2021
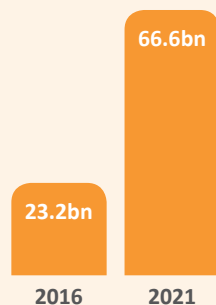
The value of the global remote consultation market is expected to reach 66 billion USD by 2021, at a compound annual growth rate of 18.8% from 2016 onwards[8].

MDLIVE®

MDLive allows users to have a consultation with a physician of their choice in order to receive healthcare for non-emergency medical conditions and various behavioural issues. Support is provided over the phone or via a video call at any time, anywhere. Moreover, MDLive enables users to share clinical data from patient records with the physician, who can provide a prescription or referral if necessary.

welcome.mdlive.com

Remote consultation is increasingly applied in healthcare and the market is growing[6,7]. It is expected that the market will keep growing until 2021[8]. Dutch Minister of Health, Welfare and Sport Edith Schippers stated that by 2019 anyone who receives healthcare and support at home should be able to speak to a healthcare provider anytime, via a webcam if necessary[7]. Recent research showed that more than half of those who need healthcare are open to virtual doctor visits[4,9]. Other research indicated that almost 60% of healthcare professionals are in favour of remote consultation[9,10]. Healthcare professionals believe that remote consultation will improve the 'workflow' and boost income[10]. 70% believes video conferencing has the greatest potential, followed by telephone, e-mail, and text messages in second, third and fourth place respectively[10]. Moreover, researchers showed that remote consult leads to equal or better patient outcomes compared to a physical face-to-face meetings[11,12].

Factors driving growth of the remote consultation market are[2,5,8]:
- More and more people have a smartphone or another high-end device (tablet, pc, etc.). There is improved connectivity due to Bluetooth, Wi-Fi, and the introduction of 3G and 4G networks that can provide stable services. Technological progress drives the market even further.
- There is a growing demand in society for convenience and innovation and a shift towards personalized medicine. Because of rising healthcare costs, it is important to deliver cost efficient healthcare that is nevertheless of a high quality.

- The development of legislation and regulations regarding the use of remote consultation, and the possibilities for healthcare professionals to be reimbursed for them increase the use.

Remote consultation is more and more implemented in Western healthcare, although the use of remote consultation is not self-evident. Not only does it involve a lot of legislation and regulations, implementation of this type of communication within a healthcare organization also requires considerable attention. Remote consultation in the healthcare sector can only be successful if it meets the needs of its users (those who need healthcare, and healthcare professionals) and if they are motivated to start working with it[2,13]. Those who need healthcare want remote consultation that guarantees their privacy and strikes a balance between indirect and face-to-face contact, and they don't want digital healthcare to replace treatment[2]. In addition, investments in IT infrastructure remain necessary in this market segment in order to meet the growing demand, and the demand for convenience, although the technology is increasingly simplified. Finally, there are differences in opinion about the idea that remote consultation may create depersonalized healthcare instead of personalized healthcare[14].

In short, the remote consultation market is diverse and developing rapidly. New products and suppliers are entering the market and existing products are improved. Remote consultation is expected to become a permanent feature in Western healthcare.

Health information systems

> **Information is the lifeblood of medicine and health information technology is destined to be the circulatory system for that information**
>
> (David Blumenthal)

⭐ *Health information system*s comprise several information systems.
1. Electronic patient records (EPR) systems, which are usually medical administrative system, in which healthcare professionals record patient's medical data[1].
2. A personal health record (PHR) is a type of EPR used by a patient to maintain and/or manage his or her own health information. The patient may the primary user or even the sole user and may provide healthcare professionals with specific access if necessary[1-3].
3. Cloud-powered medical records or patient portals are a systematic collection of electronic health information of an individual patient. It is a digital record that can be shared among patients, healthcare professionals, family, etc[3,4].

Health information systems reduce the chances of errors in management and distribution of patient records. Moreover, (incomplete) records can be easily updated. Finally, quick access to patient records leads to more knowledge among healthcare professionals about how someone is doing, and helps to determine the optimal dose of medication more adequately[5,6]. In 2015, Dutch Minister of Health, Welfare and Sport Edith Schippers stated in the annual eHealth-Monitor that from 2019 onwards at least 80% of people with chronic diseases and 40% of all other Dutch people will have direct access to certain medical data, including medical information, vital signs readings, and test results[7]. Patients have been interested in the possibility of accessing their own medical data for some time, as revealed by a poll by the Dutch patient federation, in which 83% of the participants indicated they would be interested in this[8].

dr chrono

DrChrono is a health information system that gives healthcare professionals access to electronic health records of patients via an online platform and several high-end devices due to mobile applications. DrChrono integrates various planning and scheduling tools, an administrative tool for invoices and electronic prescriptions, and the possibility to order lab tests. Patients are also able to view and manage their own electronic medical records by using the app OnPatient. DrChrono meets stringent privacy and security requirements and aims to increase the efficiency and improve the quality of healthcare.

www.drchrono.com

Quli
Zorg voor jezelf

Quli is a health information system in which the patient can be safely in charge of his own medical data and share it with family, friends, and healthcare professionals. It is up to him or her to decide who has access to which data.

Patients can share their needs with healthcare providers, who will only take action if necessary. It enhances the patient's capability to cope independently, and results in less time-wasting, and more time for personal attention and quality from the healthcare provider.

mijn.quli.nl

**Value of the global
health information systems market 2014-2022**

20.0bn

29.1bn
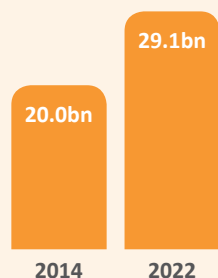
2014

2022

The value of the global health information systems market is expected to reach almost 30 billion USD by 2022, at a compound annual growth rate of 5.0% from 2014 onwards[9].

HERE IS MY DATA™

Hereismydata™ offers users a health information system that gives them insight into all aspects of their health by linking various healthcare systems, combined with data from holistic tracking devices. The user decides who can access the data. It can be shared with friends, family members, or healthcare professionals, for example. Users are in charge of their own health and can use the data to, among other things, have an equal conversation with a healthcare professional about their health.

www.hereismydata.com

The global EPR market is growing and its value will continue to rise until 2022[9]. It is estimated that currently almost 10% of Dutch adults are using or have used PHRs[5], a number that has hardly gone up since 2013[8]. A report by Nictiz confirms the 10%[10]. However, a prospective research study described that by 2015, 20% of adults in the USA would make use of PHRs, and estimated that this number would rise to more than 50% by 2025[11]. Remarkably, in Estonia the entire population is already linked to EPRs[12].

Factors driving the growth of the health information systems market are[9,13,14]:
- More and more people have a smartphone or another high-end device (tablet, pc, etc.). In addition, health records will become increasingly 'mobile friendly'.
- Increasingly, patients prefer to be in charge of their own healthcare. In addition, there is greater awareness of giving patients access to critical medical information and the opportunies to let them participate in their own health, which results in patients paying more attention to their health. Because of the rise in healthcare costs, a search for cost effective solutions is initiated.
- There are new technologies that will improve both the quality (up-to-date & accurate) of health information systems and their implementation. The possibility this technology offers to reduce the chance of medical errors will further drive the market.
- Political factors, such as the Health Information Technology for Economic and Clinical Health Act (HITECH) in the United States[11], lead to greater use of health information systems.

The rise of health information systems is imminent in Western healthcare. However, there are risks and challenges associated with this technological development too. First of all, there is the risk of cybercrime or breach of privacy[6,15-17]. Advanced software, legislation and regulations will need to eliminate this risk. Second, with PHRs and patient portals the responsibility for the content will rest primarily with the patient. The question is whether all patients are equally capable and motivated to take on this new responsibility[6,15]. Ultimately, nobody is obliged to create a record, or to maintain it[18].

Furthermore, it is important that health information systems meet the information needs and functionality of patients and healthcare professionals. This will make it easier to implement these systems and resistance can be avoided[4,19]. Finally, the lack of system standardization and the multitude of standalone, local systems also pose a risk. They may hamper the exchange of information and result in more follow-up, time-wasting, and costs[4,6,17].

Health information systems offer various opportunities for the healthcare sector. For several years, people in the Western healthcare system have been working on a central system that enables users to exchange information easily and safely. The question is not *whether* health information systems will be put in place, but when and how.

Online social networking

> **Think of social media as a live, 24/7/365 focus group**
>
> (Katie D'Arcy)

⭐ *Online social networking*, or social media for short, is a platform that is constantly evolving[1]. The term refers to an internet-oriented tool that enables individuals and communities to create and share content, and to engage in social interactions and real-time collaborations. It comprises media such as social network sites, collaborative services, blogs, wikis and virtual communities. Facebook, Twitter, LinkedIn, YouTube, Wikipedia and Whatsapp are some well-known examples[2-6].

📦 Social media has created large global networks that have the power to disseminate information quickly, to mobilize large numbers of people, and even bring about political change. Online social networking offers opportunities for both healthcare users and healthcare professionals to share and search for information. It enables users to discuss health policies and practical issues, promote healthy behaviour, exchange data, provide each other with accurate information, quickly disseminate information, grow networks and interact with others[3]. Users include patients, healthcare professionals, colleagues and students[2]. It is a fast moving community in which users can generate their own content and engage in open, two-sided dialogue[7].

f > 1.5 billion users;
annual growth rate of 15% in user numbers[8-10]

> 300 million tweets per day[11]

You Tube > 4 billion views per day[12]

> 40 million articles;
> 20,000 articles per month[13,14]

The Cystic Fibrosis (CF) café is an initiative of the Dutch Cystic Fibrosis foundation. It is an online community where (parents of) patients with CF can get in contact with each other, share experiences and exchange information. Members can create their own profile, start a weblog or place comments on weblogs written by others, and start discussions on a forum. The 'café' will soon be moved to the website www.ncfs.nl.

www.cfcafe.nl

Smart Patients

Smart Patients is an online community for patients and healthcare professionals where they can learn from each other in order to improve healthcare. The site comprises a range of communities for different illnesses where members can share their knowledge and experiences, and search for and discuss the latest clinical trials and medical breakthroughs. By tagging messages members of other communities can easily find specific conversations because of the tags they have subscribed to.

Share your story.
Stories about living with illness deliv... inspiration. Share yo...

FIND STORIES O...

www.smartpatients.com

Online social networking is flourishing, as statistics clearly show. More than 80% of American adults use the internet[15]. In 2015, 65% of American adults had used social media in the last year, compared to 7% in 2005. More and more elderly people are online too[16]. About 75% of American internet users search online for health information[4,15]. 42% of the users use social media for health related issues. Facebook and YouTube are the most popular social media platforms for these searches[17]. Nevertheless, 77% of the 'online health seekers' start their search using a search engine such as Google, Bing or Yahoo. Only 1% starts their search at social network sites such as Facebook[15]. In the Netherlands, healthcare users also frequently use the internet to search for information about illnesses or treatment (66%), or diet and exercise (49%)[18]. In addition, healthcare professionals are using social media for work more and more often, although not all healthcare professionals are in favour of this[15,19]. About 60-65% of healthcare professionals say they use social media for work, which shows a growing trend[2,20,21].

The fact that social media in healthcare is flourishing can be attributed to several factors:
- More and more people have a smartphone or another high-end device (tablet, pc, etc.). A recent report even showed that out of the time Americans spend online, 50% is attributed to smartphone applications[22]. There is improved connectivity due to Bluetooth, Wi-Fi, and the introduction of 3G and 4G networks that can offer stable services.
- There is a shift in society towards personalized medicine. The empowered patient prefers to take charge of his own health.

The flourishing market of online social networking comes with risks and challenges. Because we are developing more and more applications for sharing personal health information and also asking people to share their health information, the challenge is to guarantee the privacy of patients and the confidentiality of personal information. Care must be taken to prevent damaging the doctor-patient relationship[2,3,17,21,23]. There is a danger of hurting your professional reputation. Posting unprofessional content can have a negative and long-lasting effect on your reputation[21,23]. Moreover, through social media information is spread faster than ever. Verification of information before posting is therefore important in order to inform your audience accurately and to avoid misinformation[2,23]. The quality and reliability of information is sometimes doubtful[2,21,24].

Finally, there is a danger that the expectations of those who need healthcare will increase as a result of greater transparency. Social media makes it easy to quickly and publicly share your opinions and comments, and those who need healthcare will expect quicker responses from healthcare professionals and healthcare organizations[17].

The use of online social networking will only increase in the coming years, including in healthcare. Future patients will more than ever expect that they can gather information and communicate via these channels. The healthcare sector will have to respond to this in the right way.

Diagnosis

DIAGNOSIS comprises all analysis techniques, procedures and types of research and research results that aim to identify the cause of a health problem. In the area of diagnosis, a lot has changed in the relationship between healthcare professional and healthcare user, partly because those who need healthcare have more knowledge and information at their disposal. Technical developments put them more in control.
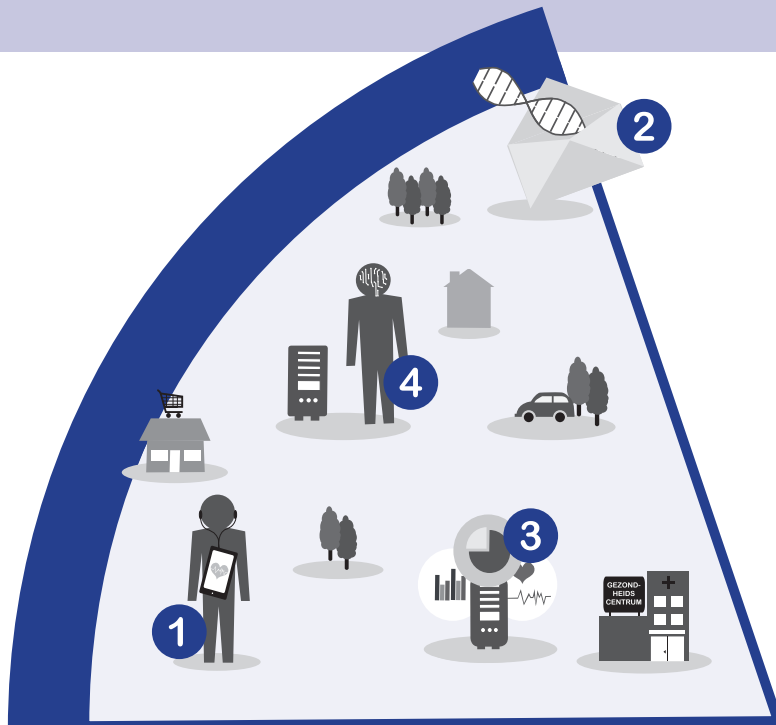
Within this phase of healthcare, the following four technological trends are identified:

1. DIY Diagnostics
2. Consumer-omics
3. Big Data
4. Artificial Intelligence

DIY Diagnostics

> ❝ **Listen to your patient,
> he is telling you the diagnosis** ❞
> (Dr. David Asch)

Do-it-yourself (DIY) diagnostics offers consumers the possibility to analyse their own symptoms or conditions through technological innovations in order to make a diagnosis. They can be used to determine the best treatment option or whether further examination is required. Some can be used to make a diagnosis without seeing a healthcare professional, while others are intended to determine whether a visit is necessary[1].

DIY diagnostics can be used for various purposes. People can, for example, measure their own blood pressure, determine the haemoglobin level in their blood, and detect diabetes, kidney failure or HIV[1]. Often, this only requires just one drop of blood, a mucus swab, a urine or stool sample, or a smartphone[2]. DIY diagnostics can be effective and reduce costs, and people's active engagement in their own health is associated with improved cognitive, behavioural, physical and affective outcomes[1].

The rise of DIY diagnostics is gathering speed. The value of the global DIY diagnostics market is expected to grow until 2021[3]. However, it needs to be noted that this estimate comprises not only the use among patients/consumers but also among professionals and in labs. A recent study by PwC showed that 83% of people are open to sharing data in order to self-diagnose. 73% are in favour of sharing data that will allow others to be diagnosed[4]. 50% of those surveyed indicated that they would want to use a DIY diagnosis test[5].

ubicomplab
UNIVERSITY OF WASHINGTON

The HemaApp is a smartphone application that enables users to measure the haemoglobin level in their blood. All they have to do is hold their finger in front of the camera on their smartphone, after which the application determines the haemoglobin concentration based on the colour of the blood. Thus users can detect anaemia in a very simple way.

www.ubicomplab.cs.washington.edu

clinicloud

CliniCloud offers a compact kit containing a non-contact thermometer and digital stethoscope that can be linked to a smartphone. These devices can be easily used at home for the purpose of DIY diagnostics. Both transmit data to the smartphone, which integrates this data into one application and helps users map their health data and recordings, and receive a diagnosis that is based on this information. The data can be shared with family members, healthcare providers, and others.

www.clinicloud.com

**Value of the global
DIY diagnostics market 2016-2021**

37.0bn

23.2bn
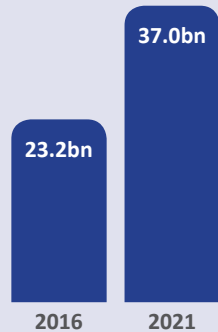
The value of the global DIY diagnostics market is expected to reach 37 billion USD by 2021, at a compound annual growth rate of 9.8% from 2016 onwards[4].

2016   2021

Factors driving the rise of DIY diagnostics are:
- DIY diagnostic devices are getting smaller, easier to carry and more accessible to the general public[6]. In addition, more and more people have a smartphone or other high-end device (tablet, pc, etc.), the technology is developing very rapidly, and becoming less expensive.
- (Healthcare) consumers want more and more health information and more control over their health experience. They increasingly initiate the search for information about their health themselves[1]. Moreover, patients want access to on-demand healthcare, and travel or waiting times often make it no longer worth it to seek the best possible healthcare[4]. While many no longer want to travel a greater distance to receive the best healthcare either[4,5].

There is a sharp rise in DIY diagnostics, although their use also comes with risks and challenges. First of all, tests can produce unreliable or inadequate information. Second, individuals may carry out tests incorrectly, wrongly interpret results, or not have them confirmed by a healthcare professional[1,7,8]. This can lead to unnecessary uncertainty and users making the wrong diagnosis, which can be either an overestimate or underestimate[8]. As a result, a patient won't go and see a doctor, which means treatment will not take place at all or too late. This can result in serious health issues[8]. Healthcare professionals are still suspicious of the new technology. Only 43% of healthcare professionals who were interviewed indicated that they would sufficiently trust the results of a DIY diagnosis test to prescribe mediation[6].

Scanadu vitals

The Scanadu Vitals is a medical tricorder that non-invasively measures vital signs and enables users to monitor their own health. By gently pressing the device against your forehead for ten seconds, blood pressure, heart rate, temperature and pulse oxymetry can be determined, and displayed on your smartphone.

www.scanadu.com

Moreover, healthcare professionals fear that the enormous amount of information now available to healthcare seekers will have a negative impact on their relationship with a patient[1]. For people who self-diagnose, finding their own medication or treatment online in order to solve their problem may seem the next logical step. In such a situation, taking the wrong actions can have harmful consequences[8]. Meanwhile, the first guidelines for the use of DIY diagnostics have been drawn up to guarantee that they are safe[9]. An important challenge that remains is to ensure that the tools that are offered can be substantiated with evidence[1].

The possibilities for DIY diagnostics are coming from all directions, from healthcare providers as well as other parties. Increasingly, patients want to be in charge of their own healthcare and DIY diagnostics provides them with opportunities for this. How healthcare organizations and healthcare professionals deal with these diagnoses is yet to be determined. However, it is certain that they must give them a place.
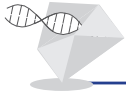
Consumer-omics

> ## "Like the early days of the internet, the dawn of personal genomics promises benefits and pitfalls that no one can foresee"
>
> (Steven Pinker)

Consumer-omics describes a trend in which it becomes increasingly easy for consumers to have access to information about their own genome, microbiome or metabolome, without any involvement of a healthcare professionals[1]. The suffix '-omics' refers to fields of science that deal with themes such as DNA (genomics), gut flora (microbiomics), metabolism (metabolomics), proteins (proteomics) or RNA (transcriptomics)[2]. Since the mid-twentieth century a lot of research has been conducted into the human genome and related research fields. Examples of this are the 'Human Genome Project'[3], the '100,000 Genomes Project'[4], the 'Human Microbiome Project'[5] and the 'Human Metabolome Project'[6]. Due to technological progress, this knowledge and research is becoming more accessible, even to the general public. 23andMe, for example, was one of the first to offer personal DNA profiles in the United States and Europe. In 2013, sale of genetics test kits was banned by the FDA, but eventually approved in 2015[7].

The technologies support a variety of personalized medicine, pharmacogenetics and pharmacogenomics. They help patients and healthcare professionals to optimize the dosing of medication[8] and consumers can proactively work on their own health and healthcare. Knowledge of genetic diseases, for example, enables people to make informed choices. The technologies offer them the chance to learn more about their ancestors and they can be used in preconception screening[8,9]. Finally, they make it possible to unravel the course and interaction of diseases and to develop faster and better diagnostics and treatments.

Consumer-omics is experiencing turbulent growth in Western healthcare. Consumer genomics is expected to make up the largest segment in the coming years[10] with a global market value of $20.0 billion in 2020 compared to $12.4 billion in 2015. This is a compound annual growth rate of 9.9% over the period 2015-2020[11].

23andMe

23andMe offers users a DNA collection kit and determines, based on the DNA in the collected saliva sample, whether the user has a genetic disorder or chance of developing a certain disease. A health report is drawn up, which contains information about various genetic diseases, the genetic effect on certain drugs, and the genetic risk profile and genetic characteristics of the user. Because of legislation in different nations, 23andMe is only available in a few countries.

www.23andme.com
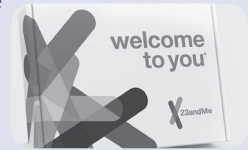
uBiome

SmartGut™ offers users a microbiome collection kit in order to analyse the microbiome of the user based on a stool sample. Users receive a report that looks at their microbiome and compares it with the microbiome of a healthy population. Thus SmartGut™ enables users to understand their gut health and composition of gut microbiotics. They gain concrete information that they and their doctor can use to determine subsequent steps. SmartGut™ is currently only available in the United States.

www.ubiome.com
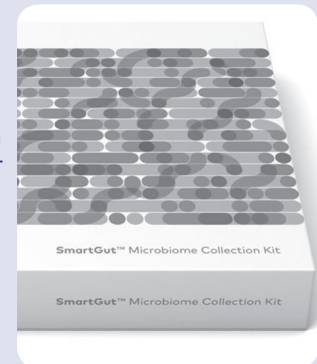
Value of the global consumer genomics market 2015-2020

20.0bn

12.4bn

2015   2020
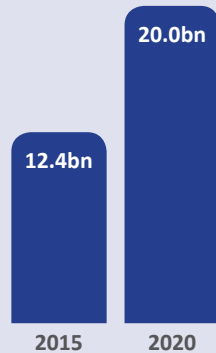
The value of the global consumer genomics market is expected to reach almost 20 billion USD by 2020, at a compound annual growth rate of 9.9% from 2015 onwards[11].

VeritasGenetics

Veritas Genetics offers users whole genome sequencing based on a saliva sample. The results are presented in a detailed report that includes: health related insights, lifestyle trait related insights, whether the user is a carrier for certain conditions, and ancestry. It also includes lifestyle suggestions and recommendations on topics the user may want to discuss with his or her GP.
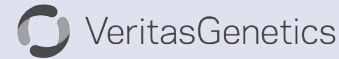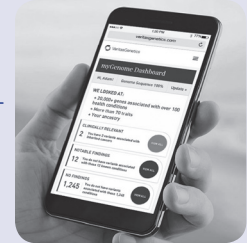
www.veritasgenetics.com

Factors driving the rise of the consumer-omics market are:
- The development of new high-throughput techniques, including next generation sequencing and whole genome sequencing, is speeding up the process and lowering the cost of genome sequencing. It is expected that eventually it will be cheaper to sequence a whole genome instead of just a few pieces of DNA[8,12,13]. Sequencing your whole genome used to cost $3 billion, nowadays it can be done for less than $1.000[13,14].
- Increased knowledge of genetics and the influence of the genome on chronic diseases leads to new applications[15]. In addition, progress in data processing technologies (f.e. big data) makes it possible to process the large amounts of data[8].
- Strategic alliances between big players in biopharmaceuticals, genetics, labs, and academic medical centres drive the consumer-omics market to great heights. For example, 23andMe signed a partnership agreement with Pfizer, Google's Calico Life Sciences with AncestryDNA, and Helix has been collaborating with parties such as the Mayo Clinic for some time[16].
- There is growing acceptance of test kits among consumers. For example, Genomics England's project 'Socialising the Genome' promotes a national conversation about genomics and the subject becomes less complex[16-18].
- Governments are promoting (genetic) research, which drives the market even further. An important example is Obama's Precision Medicine Initiative[15-17,19].

The consumer-omics market is improving, but hampered by a few factors. The biggest threat is misinterpretation of data, mainly because healthcare professionals are not involved and not all consumers fully understand the results. Consumers may make important decisions about their health based on information that is perhaps incorrect, incomplete or not properly understood[9,16,20]. The technology's accuracy, reproducibility, interpretations and reports of findings don't always meet the standards[8,20]. Moreover, there is a risk that consumers are deliberately misled due to financial incentives[20]. And there is also a chance that companies share personal data with third parties. There is little transparency, or uncertainty about the security, privacy and commercialisation of consumer data[21]. It is important that healthcare professionals are engaged in the rapid development of consumer-omics. They need to become aware of the risks and opportunities in order to answer any questions patients may have[22].

In the future, consumer-omics will play a big role in Western healthcare and change the diagnostic process. People are becoming more aware of their health, health risks and how to deal with them[23]. Eventually, the role of healthcare will shift from a predominantly reactive model to a proactive model, in which consumers use the information to make conscious choices about their lifestyle and other interventions in order to lower the risk of disease[24].

Big Data

> "Without big data, you are blind and deaf in the middle of a freeway"
>
> (Geoffrey Moore)

Big data is defined in many different ways[1]. It is not a technology in itself, but a collective name for very large and complex digital data that is hard (or impossible) to manage with traditional software and/or hardware; nor can it be managed with traditional or usual data management tools and methods[2]. Big data is characterized by five Vs[3-5] (see box below) and leads to new insights by generating, combining and analysing data. This data comes from internal and external sources, various formats and locations, and is used for a purpose other than for which it was originally collected[2,6].

In healthcare, we distinguish five sources big data sources[7]:

- **WEBSITES AND SOCIAL MEDIA;** interaction data from social media and data from websites, smartphone apps, et cetera.
- **MACHINE-TO-MACHINE DATA;** data from sensors, measuring instruments, and other equipment.
- **TRANSACTION DATA;** health insurance claims and other invoicing data.
- **BIOMETRIC DATA;** fingerprints, genetics, blood values, scans, and similar data.
- **HUMAN-GENERATED DATA;** data from (electronic) medical records, literature, doctors' notes, e-mail and other written documents.

The five Vs of Big Data

Volume	Velocity	Veracity	Variety	Value
2.5 billion GB data per day[5,8]	50,000 GB/s internet[5]	Lots of data, little quality[5]	80% without structure[4,5]	What is the value?[4,5]

The iKnow Portal is a big data application within the clinical workstation of the UZ Brussel (University Hospital Brussels). The portal makes it possible to analyse the hospital's unstructured data. The results support decision-making, clinical trials, and scientific research, and automatically create patient groups for whom healthcare can be improved. Thus the iKnow Portal contributes to healthcare quality improvement.

www.uzbrussel.be

Dr. Watson is IBM's supercomputer, which uses big data technologies to gain insight into enormous amounts of unstructured data. The goal of Dr. Watson is for healthcare professionals to make better informed decisions about treatments for their patients. For example, Dr. Watson is currently used in the MD Anderson Cancer Center to support the diagnostic process and choices for optimal treatment pathways for individual cancer patients.

IBM INSPIRE
BEYOND TODAY'S TECHNOLOGY

www.ibm.com

Big data offers many opportunities. Dataset analyses can identify associations, patterns, and trends, and detect diseases at an earlier stage. This makes it possible for healthcare professionals and other stakeholders in the healthcare system to improve the efficiency and effectiveness of diagnoses. This leads to more suitable preventive strategies and/or medical interventions, services, and policies for individual patients[2,3,9]. And this will ultimately result in better quality healthcare, lower costs, and improved patient outcomes. Researchers say that big data can lower the costs of American healthcare by about 12-17%[10]. Big data offers potential benefits for translational research in the area of healthcare and wellbeing. Gaps in knowledge about progression and course of common and rare diseases can be filled[11]. Thus effects can be identified at population level, such as off-target effects and side effects of medication, or the prevention of comorbidities[12].

Wikibon predicts that in the coming years the global big data market will have a compound annual growth rate of 14.4% and reach a turnover of $92.9 billion in 2026, compared to $18.3 billion in 2014, with 2015 being regarded as the breakthrough moment for big data[13]. Healthcare will provide the biggest boost for growth. Others predict even faster global growth: 26.5% 2015-2020[14], 40.5% 2012-2018[15] or 42% 2015-2019[16].

The rise can be attributed to several factors[2,3]:
- The digitalization of healthcare: increasingly often, client and patient data is recorded (in a structured manner) in electronic files, which makes the information more accessible too. In addition, new sources of data are added because of the internet-of-things, holistic tracking, and high-throughput technologies, including next generation sequencing. The latter makes it possible to carry out numerous analyses that generate vast amounts of data at reasonable cost and in a reasonable amount of time.
- Faster data collection, partly made possible by the development of high-speed and inexpensive internet connections (fibre optic broadband), drive the market. Moreover, data storage capacity has expanded and become cheaper. The development of internet video streaming, social media, and mobile communication have led to further acceleration.
- In addition, data can be processed quicker with faster and less expensive processors.

Project Artemis

Project Artemis is a flexible platform that focuses on enabling healthcare professionals to make better and faster decisions in patient healthcare. Through the use of real-time analytics to support the decision-making process, project Artemis focuses on early detection of infections in premature babies in order to carry out timely interventions.

hir.uoit.ca

Big data is flourishing in healthcare, but comes with challenges too. The greatest challenge lies in the possible breach of privacy of individuals. Most medical data is anonymised. But big data combines input from various sources, which means that there is a great chance that data can be deanonymised[19]. "Is privacy a thing of the past[20]?" Related to this is the question whether people are generally that concerned about their privacy, considering the ease with which they make personal data public via social media. Increasingly often, it seems privacy is no longer a right, but something you have to pay for[19,21]. Another challenge is the centralisation of knowledge. "Knowledge is power" and there is a risk that big data will give rise to private data and monopolies of knowledge. Thus society becomes increasingly dependent on private parties[19]. The technology itself is not faultless either. Analyses still generate spurious correlations too often, or datasets are unstructured, which leads to a 'rubbish in, rubbish out'-effect[22]. Finally, there needs to be certain degree of acceptance. Will a doctor accept a diagnosis reached by a computer? After all, the doctor carries the final responsibility and is used to making a diagnosis autonomously, based on his or her own clinical insights[18,19]. At the moment, there is still a shortage of professionals who are able to implement big data in healthcare[10,15].

Nevertheless, big data will soon have a great impact on healthcare and change the diagnostic healthcare process as we know it.

Artificial Intelligence

> **By far the greatest danger of Artificial Intelligence is that people conclude too early that they understand it**
>
> (Eliezer Yudkowsky)

Artificial intelligence (AI) is a technology that focuses on making machines 'intelligent'. In this case, intelligence is defined as the quality that enables an entity to function properly and with foresight in its environment[1]. AI makes use of self-learning algorithms that analyse and process data in order to, ultimately, function independently. They can discover patterns in datasets that are too big or complex for the human brain.

Although some are still sceptical about AI[2-4], it has already entered society. For example, Apple's Siri[5], Microsoft's Cortana[6] and the supercomputers of IBM and Google that beat Jeopardy[7] and GO[8] champions. In August 2016, Singapore even launched a self-driving taxi-service[9]. The One Hundred Year study panel recently published a report in which it outlined the benefits of AI in eight domains, including transport, education and entertainment[10].

Western healthcare also rides the wave of development around AI, which is set to help improve quality of life and patient outcomes. AI can provide diagnostic and clinical decision-making support, help monitor and coach patients, and support automatic devices that assist with treatments or operations as well as the healthcare and management of healthcare systems[10]. Thus, the technology changes the cognitive tasks of healthcare professionals, offers possibilities for refined personalized medicine, and may speed up processes and make them more cost-effective[10,11].

emerald
Medical Applications

DermaCompare is a unique platform that uses artificial intelligence to diagnose skin cancer. People use the mobile app to take pictures of their skin and send them to a dermatologist. The DermaCompare system shows changes over time and highlights areas that may require close attention. Thus DermaCompare increases the accuracy and efficiency, and makes it possible to make a diagnosis sooner, reducing mortality.

www.dermacompare.com

Check a Symptom

Check a Symptom is a service within the Babylon app that is based on artificial intelligence technology that functions completely autonomously. Users enter their symptoms, answer some questions, and then the app will advise them what actions to take next. In order to give this advice, the app rapidly processes endless combinations of symptoms and data. Thus users find out very quickly what subsequent action they should take based on their symptoms.
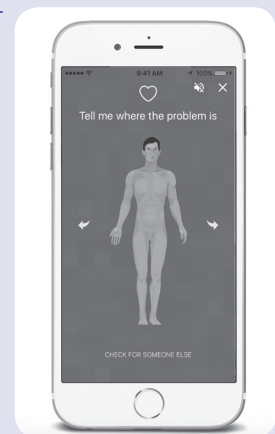
www.babylonhealth.com
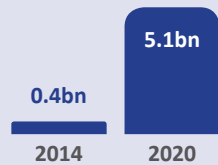
AI is growing explosively within healthcare[10]. While in 2011 there were just eight investments in AI related companies in the United States, there were 60 in 2015[12]. It is expected that the value of the artificial intelligence market will continue to grow until 2020[13]. In 2025, 90% of American healthcare organizations will have implemented AI, compared to 60% worldwide. Thus they will deliver more accessible, less expensive, and better quality healthcare to 70% of all patients, according to some forecasts[14].

The explosive growth of AI can be attributed to several factors:
- The development of more refined, less expensive and more accessible technology, such as software and hardware for entrepreneurs, combined with the rise of big data and cloud computing have lead to rapid growth of AI technologies such as deep learning[10,15,16]. AI can help the healthcare sector deal with the unprecedented amount of data generated as a result of the digitalization of society and Western healthcare.
- There is growing acknowledgment among patients and consumers that AI will contribute to the quality of healthcare and lower its costs[10,17]. Moreover, healthcare professionals are looking for ways to reduce their workload and AI can help with their search[10]. Expected shortages of healthcare staff and the prospect of rising healthcare costs will only lead to a greater demand for 'substitutions'[18,19].
- There is great demand for intelligent systems that can help meet the growing demand for clinical trials and treatment simulations, and for new treatments[17,20,21].

AI is experiencing explosive growth. However, the technology still needs to overcome some barriers before it can be fully integrated in Western healthcare. Despite growing acceptance of AI, it is necessary to, first of all, work on trust. Healthcare professionals need to become engaged with the development of AI systems[10].

Moreover, it is necessary to examine the way in which AI can take over certain tasks and how this will affect the human factor[10,22]. In addition, AI technology is also susceptible to errors. For example, the first traffic accident with a self-driving car occurred in June 2016[23]. Technical shortcomings and the need for large investments hamper wide implementation in healthcare[10] in the short-term and require a step-by-step approach[22]. Experienced, and qualified personnel need to be involved[13]. Finally, we must be careful that AI technology will not contribute to the inequality in society[7,10]. Data on which AI relies can be biased and therefore only benefit a few. There can be limited access to the technology, which leads to monopolies of knowledge. Concerns about privacy will play a role in this[10]. Stringent regulations and juridical aspects, as well as ethical considerations need to be taken into account when implementing AI technology in Western healthcare[10,22].

AI is on the rise and will have great impact on healthcare. AI will, among other things, reform the diagnostic process, although many barriers still need to be overcome in the short-term for this to happen. According to some, AI will pass the *Turing Test* for all practical purposes within the next three years[24].

Treatment & Guidance

TREATMENT focuses on recovery from physical, mental and social health problems, or avoidance of aggravation of these problems, through medical, behavioural and/or paramedical treatment. It also comprises the facilitation of nursing and care, and anticipating the patient's physical circumstances and tasks he or she will be able to perform. **GUIDANCE refers to stabilizing or activating a person's mental, social and physical performance.**

Within this phase of healthcare, the following six technological trends are identified:

1. **Digital reality**
2. **Printing procedures**
3. **Robotic systems**
4. **Exoskeletons & prosthetics**
5. **Nanotech**
6. **Advanced labs**

Digital reality

> **"We're making a long-term bet that immersive, virtual and augmented reality will become a part of people's daily life."**
>
> (Marc Zuckerberg)

Digital reality comprises technologies such as augmented reality (AR) and virtual reality (VR). AR is a technology that adds a virtual aspect, audio or visual, to reality. It basically combines reality and the virtual world[1]. VR, on the other hand, creates a virtual environment that the user experiences as the new reality. Often, VR lets a person engage in interactions in this new world[2].

The applications of digital reality are diverse. They include, for example:

- Education of medical students and healthcare professionals by projecting holograms, and through observation and performance of (virtual) operations. In addition, medical interventions can be better explained to patients and their family[3-5]. It also offers possibilities to help people understand psychological disorders such as dementia and anorexia by trying to give them more insight into the way in people with mental illnesses experience life, and improve mental healthcare.
- Rehabilitation and relearning skills[1,6-8].
- Psychological treatment of patients who suffer from illnesses such as anxiety disorders and post-traumatic stress syndrome through the use of exposure therapy[1,9-11].
- Assistance with medical tasks. In addition, digital reality can improve the diagnostic process, by turning CT scan information into 3D images, for example[9].
- Pain management, by distracting patients during painful procedures, helping them to relax, or taking away their fears, for example. It may also reduce phantom pain[10,12,13].
- Improvement of patients' mental wellbeing, by giving them the feeling that they are at 'home', for example. On the other hand, it can also relieve social isolation in people who are housebound[9,14].

Digital reality can lead to a reduction of healthcare costs due to improved or faster patient outcomes. Simulations and the possibility for healthcare professionals to virtually observe and learn from colleagues[15-17] could compensate for expected healthcare staff shortages[18].

VRphobia uses virtual reality as a therapy in combination with physiological control in order to treat panic and anxiety disorders. The therapy involves wearing a virtual reality headset that places the patient in a virtual world where he or she can experience different stimuli associated with his or her phobia. Various phases are repeated, allowing the patient to grow comfortable with the stimuli, and thus treat the phobia.

www.vrphobia.com

COOL!

COOL! is a virtual experience for both children and adults to make them forget their pain, or help them to be more in control of their pain. Through virtual reality, patients enter an environment in which they can engage in interactions that improve their mindfulness and resilience via various stimuli. Studies show a significant reduction in chronic pain among the participants and therefore COOL! can be used as a pain management tool.

www.deepstreamvr.com

At the moment, Oculus, Sony, HTC and Samsung Gear are the biggest developers of VR hardware and software[19]. On the other hand, there is Microsoft's HoloLens for AR[20]. Since this year, most consoles are available to the general public, although many people were already familiar with VR.

The market of digital reality in healthcare is experiencing explosive growth. While in 2016 the turnover of the global digital reality market was estimated at 'just' $5.2 billion, it will amount to more than $162 billion by 2020, according to IDC[24]. Over the period 2015-2020, the compound annual growth rate of the market will be no less than 181.3%. Currently, VR is the largest segment, but after 2017 there will be a more more equal distribution with AR[24]. For healthcare specifically, the value of the global digital reality market is forecasted to grow from $1.2 billion in 2014 to more than $2.5 billion by 2020. The greatest numbers of digital reality applications are expected to be seen in the areas of training and rehab[25].

Driving factors behind the rise of digital reality in Western healthcare are:
- The cost of technology is falling and technology is becoming more practical, more accessible to the general public, and used for new purposes[26,27]. Technological developments promote market growth. These include smaller screens with higher resolution, more accurate gyroscopes to determine the orientation of the device, and more (and more compact) computing power to allow for a high number of images per second and fast image processing.
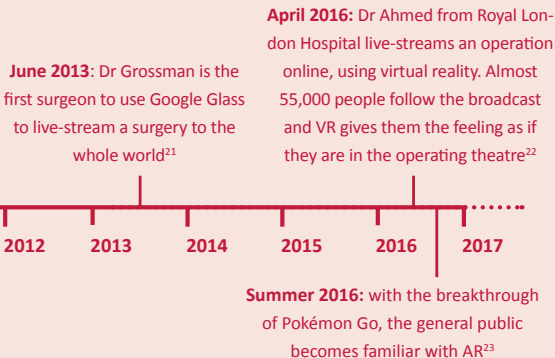
AccuVein®

AccuVein uses augmented reality to help healthcare professionals to, for example, carry out venipunctures. A scanner visualizes the location of the veins on the patient's skin, which improves the likelihood of successfully hitting the vein on the first try by about 3.5 times. AccuVein contributes to patient satisfaction, cost control, and quality of healthcare.

www.accuvein.com

- Growing pressure to deliver effective healthcare, due to higher healthcare costs, calls for cost-effective solutions[28]. Digital reality applications are showing to have positive effects on human health and cover the areas of addiction, strokes, and mental and behavioural disorders[2,6-12].

Digital reality is a promising technology and will play a great role in the future. However, the costs are currently too high, keeping many applications out of reach[29,30]. Second, the technology is still very complex and gains can be made in education and use[30]. Third, often the technology itself still comes with limitations, such as the headsets' limited field of vision and the fact that they are not always wireless[31,32]. Fourth, there is a lack of regulations for the use of digital reality and privacy is not guaranteed due to limited security[29,33]. Finally, some health effects need to be considered. For example, it is known that VR lead to irritation and sickness, also known as motion sickness[32,34,35]. In addition, the headsets can cause irritation because they are not always comfortable to wear, They can also lead to stress or anxiety, because they give users the impression of being completely cut off from reality[35].

Nevertheless, developments in digital reality will have a considerable impact on Western healthcare. It allows us to see the way in which treatment and guidance are provided in a different light.

Timeline digital reality in Western healthcare

June 2013: Dr Grossman is the first surgeon to use Google Glass to live-stream a surgery to the whole world[21]

April 2016: Dr Ahmed from Royal London Hospital live-streams an operation online, using virtual reality. Almost 55,000 people follow the broadcast and VR gives them the feeling as if they are in the operating theatre[22]

2012   2013   2014   2015   2016   2017

Summer 2016: with the breakthrough of Pokémon Go, the general public becomes familiar with AR[23]

Printing procedures

"Bioprinting has the potential to change the world"

(Jeff Kowalski)

Charles W. Hull came up with the concept of 3D printing in the late eighties[1] but did not foresee its future impact. 3D printing is a production method in which objects are constructed three-dimensionally. It uses materials such as plastics, metals, ceramics, powder, fluids, or even living cells and adds these layer by layer. With this technology, radiographic 2D images, such as X-rays, MRIs or CT scans, can be used to form 3D images[2,3]. Thus it is possible to manufacture tailor-made products on-demand.

More and more materials can be used in 3D printing and thus in healthcare. Examples are printed dental crowns, bones, prosthetics, skin, and medical tools, but also food (supplements) and medications. 3D printing was initially regarded as a way to optimize pre-surgical planning. But has since been recognized for its potential in clinical training, research, patient education, the creation of adapted prosthetics, and even replacement of functional tissues and organs. 3D printing of functional tissues and organs is also known as 3D bioprinting[4]. In 2015, the American FDA approved the first 3D printed medicines[5].

3D printing has several benefits: it is often less expensive, faster, and can be customized. 3D printers are able to print complex structures. Directly printing a digital model enhances precision and reproducibility. Moreover, the technique omits waste and extra costs, as 3D printing is an additive rather than a subtractive process[2,3,6]. For healthcare professionals there are benefits too. Models that are printed in advance can be used to prepare for surgical procedures. This reduces the risks during complex procedures, the risk of infections, and the time spent under anaesthesia. Finally, 3D printing technology can replace animal testing and the pharmaceutical industry can change the way in which it develops and tests new medications[3,7].

eNABLE is a community that uses 3D printing to print hands and arms for free for those who need them. Via its open-source network anyone can submit, download, and print different designs. eNABLE aims to further develop and perfect 3D printed prosthetics through collaboration and innovative ideas.

www.enablingthefuture.org
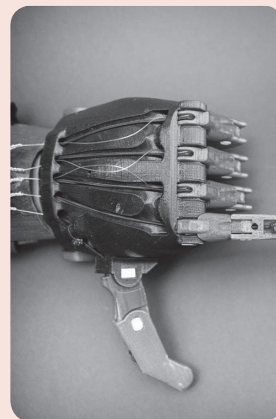
ExVive™ Human Kidney Tissue is human kidney tissue that is entirely 3D bioprinted. The tissues are printed under strict conditions in order to guarantee their quality. ExVive™ Human Kidney Tissue enables users to thoroughly investigate the effects of medications and specific treatments on kidneys. Thus ExVive™ Human Kidney Tissue provides opportunities for advanced drug research, for example.

www.organovo.com

Value of the global 3D printing in healthcare market 2014-2020

2.4bn

0.6bn

2014   2020
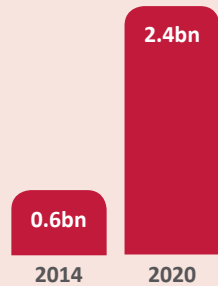
The value of the global 3D printing in healthcare market is expected to reach 2 billion USD by 2020, at a compound annual growth rate 26,2% from 2015 onwards.[7]

The market of 3D printing in healthcare is growing. It is predicted that the value of the global 3D printing healthcare market will continue to grow until 2020[7]. Especially for purposes such as prosthetics, implants and education a sharp rise in 3D printing is expected[8]. Gartner predicts that in 2019: 10% of the global population will have 3D printed products in their lives, 3D printing will fulfil a key role in 35% of surgical interventions in which prosthetics and implants are inserted, and further technological and material innovations will result in 10% of generic drugs being produced by 3D printers[9].

The rise of 3D printing in Western healthcare can be attributed to several factors:

- There is an increased focus on personalized medicine in Western healthcare and growing demand for tailor-made products. For example, prosthetics, implants, and medication can be customized[2,7,8]. Due to the falling prices of 3D printers and the diversity of available biomaterials, the number of application possibilities is growing[3,10,11].
- There is a growing need for organ transplantations. This is partly due to an ageing population and to complications associated with old age[10-12]. Growing acceptance of 3D printed tissues and organs among the Western population promotes further growth of these applications[10,11].
- More and more companies are focusing on the technology. There is a rise in investment, research, mergers and acquisitions to increase market share, as well as a growing number of expiring patents, which opens up opportunities for new entrepreneurs[10,11,13].

3D printing is experiencing rapid growth and is already used in many areas. In order to embed the technology in healthcare, more challenges have to be overcome, including high costs. Despite the falling prices of 3D printers, advanced printers still cost tens of thousands of euros[4,7,10,11]. Second, legislation and regulations hamper development and application[7,10,11]. Third, there are still technical challenges remaining. Despite safety, precision, and reusability, current models still differ too much from human tissue in terms of texture[4,14]. Experiments are taking place[14], but producing entire organs remains a challenge[15]. It takes a lot of time and energy to isolate areas for 3D models. This affects cost-effectiveness and reduces usability in urgent cases. Companies try to speed up these steps by renewing the software[4]. Finally, few research studies have been completed to determine the impact of 3D printing for medical purposes versus conventional methods. These larger studies are necessary to evaluate whether shorter operative times, reduced revisions, and shorter hospital stays justify the extra costs to produce 3D models. Printed 3D anatomic models have already proved their value in the area of training and education of healthcare professionals[4].

3D printing is a powerful instrument for the future. It has proven its worth when it comes to creating anatomic models to assist with complicated operations, training of healthcare professionals, the creation of adapted prosthetics, implants and medications. 3D printers continue to expand their capacities, reduce costs, increase speed, and expand applications for printable materials. When parallel progress takes place, 3D printing will gain a stronger market position and its applications within Western healthcare will expand.

Robotic systems

> **The central question of 2025 will be: What are people for in a world that does not need their labour, and where only a minority is needed to guide the 'bot-based' economy?**
>
> (Stowe Boyd)

Robotic systems comprise robotics that make automated execution of (medical) tasks possible through the integration of a variety of external information. Thus patient outcomes, patient safety, and patient satisfaction can be improved. Robotic systems help healthcare professionals provide treatment and guidance to patients. The technology comes in many shapes and sizes, such as precision robotics for operations and medical tasks, and robotics that automate and support everyday tasks in healthcare facilities[1]. They perform tasks that (healthcare) professionals cannot carry out as well or as efficiently[1].

These technological innovations bring widespread benefits. Medical treatment can be less invasive and more comfortable for the patient, or provide opportunities to carry out faster, smaller, and more precise interventions. It enhances the healthcare professional's dexterity and access during an intervention. This may result in shorter hospital stays, increased patient turnover, lower risks of (hospital) infections and other (post)operative complications, and financial savings[2-8]. In addition, robotic systems can support or entirely take over certain tasks of healthcare professionals. Thus they reduce the workload, increase the stamina of the healthcare professional, and provide a solution for the outlined staff shortages in the future[1-3,9,10]. Finally, the robotization of medical tasks offers the possibility to carry out interventions remotely[2,11,12].

The global robotic systems market is growing and expected to reach a value of $20.5 billion by 2022, compared to $8.9 billion in 2015, with a compound annual growth rate of 12.1% over the period 2015-2020[13].

VenousPro™

VenousPro™ is a robotic arm that can draw blood from a person. The robotic arm combines 3D infrared technology and ultrasound imaging to select the most suitable vein. A member of staff is only needed to operate the machine, because the procedure for drawing blood is carried out automatically. Thus the robot offers a safe and fast way to hit the vein on the first try.
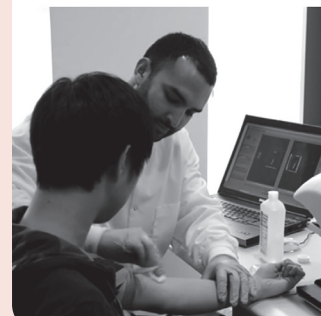
www.vasculogic.com

AETHON

The TUG is a smart autonomous mobile robot that helps healthcare personnel with logistic tasks. The robot can haul and transport goods, materials, and clinical supplies within a healthcare facility and used in several ways. The TUG robot has an array of sensors, which enable it to determine its own route. Use of the TUG robot may lead to reduced costs and increased efficiency, safety, and employee satisfaction.

www.aethon.com

Value of the global robotical operations market 2015-2022

20.5bn

8.9bn

2015 **2022**
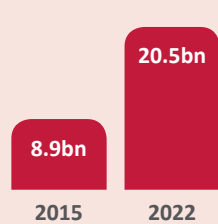
The value of the global robotical operations market is expected to reach 20 billion USD by 2020, at a compound annual growth rate of 12.1% from 2016 onwards[13].

Medrobotics
Expanding the reach of surgery ®

The Flex® Robotic System is a precision robot that enables surgeons to access anatomical locations that were previously difficult or impossible to reach minimally invasively. The precision robot consists of a flexible robotic arm that is equipped with a HD camera, lasers, graspers and other instruments, which the surgeon controls with a joystick. Thus the Flex® Robotic System expands the possibilities for minimally invasive surgery.

www.medrobotics.com

The increased use of precision robots in surgery accounts is the biggest contributor to this growth[13,14]. The introduction of the Da Vinci® robot in 2000 is still the best-known example; more than 3,600 of these machines have since been implemented in hospitals around the world[15]. Fortune predicts that within the next five years, one in three operations in the US will be carried out by a robot[15].

The rise of the technology within Western healthcare can be attributed to various factors:

- Demographic developments such as an ageing population and the rise in the number of people with chronic diseases and with multimorbidity increase the demand for healthcare. In addition, increased healthcare costs[16], expected healthcare staff shortages[10], and a higher incidence of preventable side effects and medical errors[17,18] lead to a search for alternative ways to treat patients[1,5-8,11,19].
- There is a growing demand in Western society for more personal and better quality healthcare, and a better patient experience. In Western society, there is a growing awareness of the advantages of robotic systems, and growing acknowledgment that robots can and should carry out medical tasks. We see a gradual shift from conventional surgery to minimally invasive surgery, and ultimately non-invasive surgery[5,14].
- The possibilities are further enhanced by the rise of artificial intelligence and improvements in software, for example in the decision-making capacity and autonomous functionality of robotic innovations[1,5,20,21].

The implementation of robotic systems is on the rise, but there are still risks and challenges ahead. Organizations have to invest in the skills of healthcare staff, because they have not yet been trained to work with the latest robotic innovations[2,5]. Currently, there are hardly any large producers of robotic systems and the price can be kept high due to limited competition[2]. There are opponents who fear that robots will take over their jobs in healthcare[9]. In addition, there is *more* technological progress to be made. For example, a small delay still exists between the moment a healthcare professional moves a joystick and when the robot responds. Moreover, some argue that the use of robots for the performance of medical tasks actually takes *more* time[15]. The risk of errors resulting from incorrect instructions, broken machines, or system failure still exists[2,6]. The latter raises an ethical question: Who is guilty when something goes wrong and only a robot has touched the patient[3,22]? Privacy and the safety of the technology need to remain guaranteed too, as autonomously operating robots, for example, could be attractive targets[3]. Finally, it will be necessary to take another look at legislation and regulations, although current legislation hampers growth[1,5].

Once greater numbers of healthcare professionals will become more familiar with robotic innovations and their benefits are assessed, robots will eventually become a permanent feature in patient care.

Exoskeletons & prosthetics

> **Indeed, through fundamental advances in bionics in this century, we will set the technological foundation for an enhanced human experience, and we will end disability**
>
> (Hugh Herr)

Exoskeletons are wearable bionic devices with motorized joints to enable the user to simulate the affected biological joints[1,2]. Integrated technologies increase the functionalities of the user and improve his or her performance[1,2]. Research into the development of exoskeletons was originally intended for military purposes, but exoskeletons have slowly entered Western healthcare[3]. *Prosthetics* are artificial devices that replace a user's body part. Previously, there were only aesthetic 'replacements', but now advanced bionic prosthetics are available, which combine advanced technologies. They replace or even improve limb functionalities[4,5]. Prosthetics come in many shapes and sizes, such as limbs[6], eyes[7], ears[8], and even organs[9]. Ultimately, it will become possible to build an entirely bionic human being[10]. But here, we only focus on limbs.

The technologies offer various benefits. Exoskeletons can support and motivate patients during the rehab process. That is because they offer more intensive and correct training, quantitative feedback, active initiation of movements, and, ultimately, better patient outcomes[11-13]. In addition, exoskeletons and prosthetics make users more autonomous. They help them walk and stand, carry (heavy) objects, and perform everyday tasks[14,15]. The technologies offer possibilities to keep users active, independent, and healthy for longer, and they reduce the effects of disabilities, muscle dystrophies, paralyses, or fatigue[11,15]. Finally, the mental state of users can be improved, because they no longer feel like 'outsiders'[16].

JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

The Modular Prosthetic Limb (MPL), developed by Johns Hopkins University, is an advanced prosthetic arm that can be controlled by the mind. The arm is equipped with more than 100 sensors and enables users, who have undergone a conventional operation named targeted sensory reinnervation, to have the sense of touch. The MPL is still in development and may eventually be able to detect pain as well.
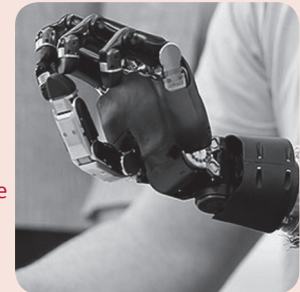
www.jhuapl.edu

Ekso GT™

The Ekso GT™ is a wearable robotic exoskeleton that enables users to stand up and walk while carrying their entire natural weight. In order to walk, users shift their weight, which activates the sensors and initiates steps in the desired direction. Battery powered motors move the legs to replace the inadequate neuromuscular function. The exoskeleton is designed for people with varying levels of paralysis or hemiparesis caused by neurological disorders.

www.eksobionics.com

Value of the global exoskeletons market 2015-2025

0.03bn — 2015
3.3bn — 2025
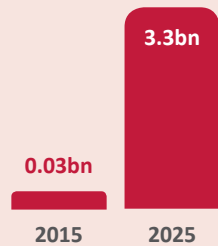
The value of the global exoskeletons market is expected to reach more than 3.3 billion USD in 2025, at a compound annual growth rate of 63% from 2015 onwards[17]. The value of the bionics market will reach more than 20 billion USD by 2021, at a compound annual growth rate of 13.2%[18].

BIONX
Inspired by You.

The emPOWER ankle is an advanced prosthetic ankle that restores the function of the leg. The emPOWER ankle is intended for people who have undergone either above or below the knee amputations. It enables users to take up an active lifestyle again. Due to technological progress, its safety and stability have improved and users can walk with less fatigue.

www.bionxmed.com

The markets for exoskeletons and prosthetics are growing and the value of the exoskeletons and bionics markets will continue to grow until 2025 and 2021, respectively[17,18]. Limb prosthetics currently make up the largest segment of the bionics market and this will remain the case throughout the above-mentioned time period[18].

Factors driving this market growth are:
- The demand for efficient technologies to assist with rehab, the care for elderly people, and everyday tasks rises because of demographic developments and a growing number of people who suffer from neurological diseases[2,12,17,19,20]. In addition, the number of (sports) injuries and trauma cases, which can lead to paralyses and amputations, is still growing[1,18,19,21].
- There is a growing desire in Western society for more personal healthcare, better quality healthcare, and a better patient experience. Society wants a better quality of life and more autonomy[19]. In addition, society strives for superior performance of the human body, as often seen in sports[21,22].
- Current rehabilitation processes are usually labour intensive and often inefficient[12]. With healthcare staff shortages expected in the near future[23], the demand for efficient solutions will only grow. At the same time, people are searching for ways to help healthcare professionals lift patients and heavy objects in order to reduce the strain[2,17].
- There is growing acceptance in society of these technologies and increasing awareness of what they can offer the healthcare sector. A rise in approved products and their commercialization, as well as greater competition drive the market to new heights[17].

- Technological developments and progress, such as the possibility of mind-controlled prosthetics and 3D printing, lead to new possibilities[18,21].

The market for exoskeletons and prosthetics is growing, but there are limitations too. First of all, the purchase costs of the technology are still very high en often not covered by insurance[2,11,15,21,24]. In addition, there are the costs for maintenance and repair of the technology[24]. Second, there are technological limitations. Technological progress takes place all the time, but not everything has been solved yet. It remains difficult, for example, to correctly control movements, both physically and cognitively[1,25], while portability, weight, design, and comfort could be further improved as well[2,25]. Because discomfort results in minimal use or even disuse[24,26]. Exoskeletons still make a lot of noise too and can only be used for limited purposes at the moment[2]. Finally, the technological developments raise ethical questions. Kurzweil already stated in his book that as technology progresses and prosthetics become more advanced, they will no longer just restore functionality but improve it too[27]. There will be people who will opt to have biological limbs replaced by advanced prosthetics. Often, consequences are not yet known, so can user safety remain guaranteed? And how quickly will a technology become outdated and no longer be 'optimal'?

Exoskeletons and prosthetics will slowly integrate in users' daily life and no longer be assistive technology, but part of their identity. The first Bionic Games have already taken place[28].

Nanotech

"Why is something so small so big?"
(James F. Leary)

Nanotech describes the application of nanotechnology in Western healthcare. Nanotechnology comprises minuscule technologies, varying in size between 0.1-100nm and is therefore often even smaller than the average size of a virus (see text box opposite)[1]. Nanotech in Western healthcare comprises many different types of applications with many different functionalities. They cover various areas: diagnostics, repairs, therapies, microsurgery, and the delivery of drugs and other substances to targeted regions of the body[2-6].

Nanotech has a lot to offer to Western healthcare. Early detection and prevention, improved diagnostics, and optimal treatment and follow-up are among the possibilities[1]. Nanotech can be used as markers, which makes diagnostic tests more sensitive, accurate and reliable[1,7]. Because of the miniscule size, diagnostics and therapies are less invasive. Specific targets can be reached more easily, medication can be delivered faster and more selectively, and higher concentrations of medication can be delivered more accurately to the desired location within the body. This results in increased efficiency and effectiveness and lowers the risk of side effects of interventions[1,7,8]. Due to nanotechnology, medical equipment is small enough to be swallowed or implanted in the body, thus reducing biomedical response times. In addition, nanotech can reproduce and repair damaged tissue[1]. In short, nanotech results in personalized, more effective, and more efficient healthcare in order to improve the quality of the healthcare provided[3,9].

The nanotech market is growing because of increased use of new nanomaterials and the rise of nanorobots. For 2015, the global nanotech in healthcare market was valued at more than $212 billion and it is predicted to be worth $344 billion by 2024. With a compound annual growth rate of 5.5% over the period 2013-2020[10]. Oncology is the medical field that makes the most use of nanotech, however the largest growth is expected in the cardiovascular segment[7,10].

NBTXR3 is a watery suspension of nanoparticles treated with a special coating designed to help enter cancer cells and accumulate in the tumour. The nanoparticles help improve the dose and effectiveness of radiotherapy without increasing the toxicity in, or causing damage to, surrounding healthy tissues. The technology is still in its developmental stage and currently studied in several phase II and III clinical trials.

www.nanobiotix.com
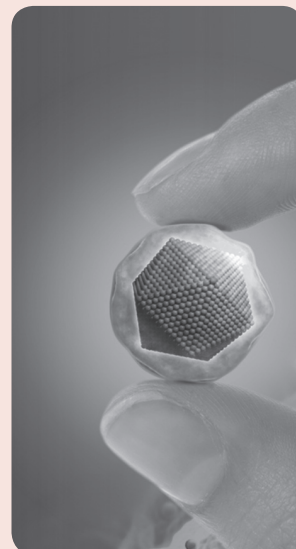
Quantum Dots

Quantum Dots (QD) are artificial light sources that are just a few nanometres in size. Because of their unique optical characteristics, they are used for targeted drug delivery within the body. Thus they increase the bioavailability and can, as nanotransporters, enable localized treatment of diseases. The benefits of QD are broad and interest in the technology is growing. Although evolving, QD applications are still in their infant stages.

Zhao et al. 2016[20]

Nanotech on a comparative scale[1]

Water · Glucose · Antibody · Virus · Bacterium · Cancer cell · Tennis ball

10^{-1} 1 10 10^2 10^3 10^4 10^5 10^8

Nm

Nanotech
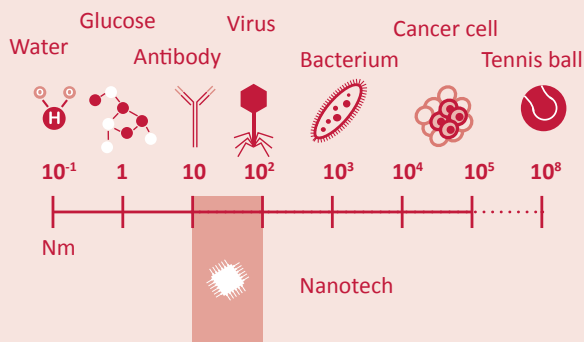
Nano Retina

The Nano Retina is a nano-implant designed to restore the vision of people who have lost their eyesight due to retinal degenerative disease. The implant is inserted into the retina in a minimally invasive procedure. It replaces the functionality of the damaged photoreceptor cells and creates the electrical stimulation required to activate the remaining healthy retinal cells. Thus, Nano Retina helps patients see again.
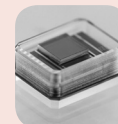
www.nano-retina.com

The rise of nanotech within Western healthcare can be attributed to the following factors:

- Demographic developments such as a growing and ageing population, and increasing incidence and prevalence of chronic diseases[7,11-14]; there is a growing demand for new and more effective medications and therapies to meet the growing healthcare demand.

- Progress in nanotechnologies and growing knowledge of nanotech pave the way for new and improved applications[7,10,12]. There is growing interest and investment in nanotech research from both government organizations and private companies. New players are entering the market, which leads to competitive and innovative insights[7,11-13].

- A growing demand in society for more personal healthcare, better quality healthcare, and a better patient experience. The rising cost of healthcare requires new therapies to be more cost-effective and to come with fewer possible side effects than conventional methods. There is a growing awareness in society of the possibilities that nanotech can offer[7,10,13,14].

Nanotechnology takes place on a small scale, but can offer great benefits to Western healthcare in the future. However, it also comes with great risks and challenges. The process from research to market introduction is time-consuming and expensive, while stringent regulations hamper market growth[7,10,13,15-17].

Others say that legislation is actually trailing behind the technological developments and therefore doesn't suppress possible risks[15]. In addition, patents are often badly protected and in many cases the return on investment is non-existent[17]. Moreover, society is still weary of the technology[17]. Nanotech comes with its own risks and the consequences and many of these consequences are yet to be mapped out[7,14,16]. The exact mechanisms and interactions of nanotechnology within the human body are mostly unknown, as are ways in which new nanotech applications may damage a person's health[15]. Healthcare professionals often lack the skills and knowledge to apply nanotech in practice[6]. This raises ethical issues, because the safety of the patient needs to be guaranteed[2,8,18]. Finally, there is the risk of cybercrime in which hackers could target technology inside the human body[19]. Education, risk assessments, and an adequate regulatory framework will partly eliminate the dangers and challenges of nanotech[17].

Nanotech has enormous potential and will play a crucial role in Western healthcare in the future. Nanotech will pave the way for new and improved treatments.

Advanced Labs

> ## "Huge sums are invested globally in medical research and development – and with good reason"
>
> (Geoff Mulgan)

★ *Advanced labs* is a theme that comprises technological developments that lead to new and/or improved (research) techniques and methods. Technological applications of advanced labs range from new gen therapies to digital research and in-silico trials. In-silico trials refer to the use of personalized computer simulations in the development and evaluation of medication, medical tools, or medical interventions[1].

◻ Technological developments in the area of advanced labs can lead to faster and cheaper development of medications and therapies[2]. By including suitable human subjects earlier, studies are set up more quickly, results are more accurate and reliable, and data can be processed faster and easier[3]. Clinical trials and animal-based studies can be minimized and even replaced because of the rise of in-silico trials, organs-on chips, and labs-on-chips[4-7]. Newly developed (research) techniques will eventually lead to innovative (cost-)effective therapies and thus improve the quality of Western healthcare[8].

↗ The market for advanced labs is growing[9]. For example, the value of the in-silico technologies market is expected to grow from $4.4 billion in 2015 to $21.2 billion in 2024[10]. The compound annual growth rate of the organs-on-chips market will be 70% over the period 2015-2020. Its value will reach $450 million by 2020, compared to $31.5 million in 2015. The first human-on-a-chip is expected by early 2018[11].

✚ Factors driving the rise of advanced labs are:
- Demographic developments such as a growing and ageing population, and an increased prevalence of chronic diseases[9,10] call for new and more effective treatments in order to meet growing healthcare demand.

CRISPR

CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats)-Cas9 is a promising DNA modification technique for targeted editing of human genes. CRISPR is revolutionary because of its relatively simple, fast, precise and inexpensive technique. DNA is cut at the desired location, allowing pieces of DNA to be added or removed. Because it can cut very accurately, the risk of side effects is minimal. Researchers hope to use the technique to repair human genes in case of genetic disorders, for example, or to fight infectious diseases. Although CRISPR was discovered in 2013, it was not until 2016 that the first clinical study was approved in which CRISPR is used to treat cancer.

Reardon S. 2016[24]

Apple's ResearchKit is an open-source software platform that enables researchers to develop mobile apps to collect research data. With the ResearchKit, scientists can collect information of potentially millions of users and thus gather more data than ever before, while patients go about their daily lives. Use of the ResearchKit results in a more varied research population, a more frequent supply of new data, and a more accurate representation of the population.

www.apple.com

UNIVERSITY OF TORONTO

Researchers at the University of Toronto have developed a person-on-a-chip. It is a 3D vascularized structure made out of POMaC that simulates living organs. Organs and interactions between organs are simulated. The AngioChip offers a platform for discovering and testing new drugs and for replacing animal and clinical studies, while also enhancing future possibilities to repair or even replace damaged organs.

www.engineering.utoronto.ca

HumMod

The HumMod is an advanced simulation model of the human body that makes it possible to study complex physiological interactions in humans. It offers models for organs as well as individual molecules and contains more than 1,500 comparisons and 6,500 variables based on literature data. The HumMod can be applied in many ways and still evolving. It can be used for research, and as an educational tool.

www.hummod.org

- Rising research costs call for cost-effective solutions[9,12,13]. For example, 75% of the total costs to develop a new drug are spent on in-vivo studies. Therefore, failures in phase II or phase III trials lead to great financial losses[1]. The pharmaceutical field is encouraged to increase efficiency and productivity[14]. There is also a growing trend in Western society towards personalized medicine[9,10,13]. New therapies need to be faster and more accurate, and side-effects need to be prevented[12,15].

- There is a growing awareness of the possibilities advanced labs can offer to replace clinical studies and animal-based studies and to develop new therapies, while the need for more research, in order to achieve this, is increasingly acknowledged too[9]. Increasingly often, patients take centre stage and become 'partners' in research, playing an active role in studies and submitting data via connected wearables and apps[12,16].

- Growing knowledge, technical progress, and technological developments such as big data, artificial intelligence and 3D printing lead to new insights and possibilities[3,10-13,15-18]. Digitalization could reduce the time, effort and money spent on collecting data in clinical studies[19]. For example, recent research showed that 64% of the pharma and biotechnology companies surveyed already use digital technologies in clinical studies and almost 100% expect to use them in the next five years[16].

Advanced labs lead to new insights in healthcare, but come with challenges too. Because of the rapid developments, it is difficult for healthcare professionals and patients/consumers to keep informed about the latest innovations[15]. In addition, developments in pharmaceutical companies are hampered by the relatively slow implementation of new technologies[19]. Second, research studies are becoming increasingly complex and harder to manage because of the growing bulk of knowledge and advanced technologies[11,20]. Costs rise because of the need for the latest equipment, and errors can creep into studies more easily[11]. The digitalization of society and technologies such as big data may lead to errors becoming interwoven into the growing amount of data. The data may also lose its integrity as patients play a more active role in studies and submit their 'own' data[21]. Finally, technological progress also raises ethical questions: Is the privacy of the data used in studies guaranteed? Are previous studies, on which new research is based, valid? Can patient safety be guaranteed in new therapies[20,21]? And what do we know about the consequences of, for example, new genetic modification methods? Where do we draw the line (between ethical and unethical)[22]?

Legislation and regulations, along with frequent validation will be required to guarantee the privacy and safety of patients as well as the quality of healthcare[21], although some say these factors actually hamper development[23]. We will have to start a dialogue to discuss ethical issues and the technology will have to evolve[22]. Digitalization leads to centralized research and 'team science' is promoted[14]. Advanced labs will reform Western healthcare and provide opportunities for new research methods and treatments.

Control & Monitoring

CONTROL comprises the verification that treatments and support achieve the desired effect in patients as well as the verification of compliance.

MONITORING can be a tool for control, for examining progress, and for reactive compliance.

Within this phase of healthcare, we identify the following three technological trends:

1 **Domotics**
2 **Remote monitoring**
3 **Robotic care**

Domotics

> ## "There's no place like home"
> (Judy Garland)

Domotics comprise the application of sensors and communication technologies in the home or other living areas to support patient care[1]. We distinguish two types of applications: monitoring and guidance. Monitoring technologies comprise alarm, signalling, and security systems. These vary from simple, portable alarm buttons to intelligent systems that can detect whether a person deviates from his or her normal behavioural patterns. Guidance technologies ensure that the environment is actively or passively regulated, operated, or checked[1].

Domotics offer the possibility to deliver 'remote healthcare'[1]. The healthcare process can be organized more effectively and efficiently. Domotics help elderly people or patients to remain in their own home for longer, thus indirectly increasing a person's self-worth[1-3]. They offer elderly people or patients greater freedom of movement and enhance the quality of life and independence[1,3]. Elderly people, patients and healthcare professionals can be tracked in real-time[4]. In addition, domotics can help healthcare professionals and carers deliver care and increase efficiency. Thus they reduce the burden on healthcare personnel and offer a solution for future shortages of healthcare professionals[1,3,5]. Ultimately, domotics provide faster, safer, more preventive care and can be used to reduce the healthcare costs[4,6,7].

The domotics market is growing. The global domotics market is expected to grow by 38% over the period 2016-2022[2]. Applications in fall detection and prevention will experience the largest growth[2]. The recent Nictiz eHealthmonitor showed that more than 60% of healthcare organizations indicate to be actively working with domotics[8].

This increase can be attributed to various factors:
- Demographic developments such as an ageing population and increasing life expectancy[9] as well as the growing incidence of chronic diseases[10] lead to a greater demand for healthcare and increase the demand for domotics[2,11-13].

OPENXS
Smart Optical Sensor

The Smart Optical Sensor (SOS) is a self-learning, ceiling mounted sensor that detects behaviour resulting in an incident. When the alarm is raised, SOS sends a message to a handset or smartphone that includes a description of the possible risk. Healthcare professionals are able to watch a brief video clip to see what caused the alarm to be activated, assess the situation and decide whether it is necessary to take action. The SOS is truly 'client'-focused.

www.openxs.eu

livesafe®

TheLifeSafe comprises a special mobile alarm device that automatically connects users to emergency services at the push of a button, anytime, anywhere. It shows the GPS location of the user sending the distress call and links to online personal records, mijnLiveSafe (myLifeSafe), to ensure the most suitable help can be provided quickly. Thus it enhances the user's autonomy.

www.livesafe.nl

Value of the global domotics market 2016-2022

2022

2016

Between 2016 and 2022, the global domotics market is expected to grow by 38% per annum[2].

pillo

Pillo is a smart medicine dispenser. Due to intelligent software, it gets to know household members and makes sure that the right person takes his or her medication or supplements at the right time.
Pillo can also notify carers when users have missed their medications and orders refills when required. In addition, Pillo can answer health and wellness questions and connect users directly with a doctor for a teleconsultation.

www.pillohealth.com

- The majority of elderly people spend most of their time inside the house and combined with a significant rise in the number of elderly people who live on their own, it is no surprise that most (accidental) falls occur indoors[4].
- The growing need for cost and time efficient healthcare (in combination with technical progress and technological developments such as the Internet of Things, smartphones and improved connectivity) drives wider implementation of domotics[2,11-14].
- There is a growing awareness of the convenience and possibilities that domotics can offer. In the shift towards personalized healthcare and 'empowered' patients who place high demands on the care they receive, domotics provide a solution[2,11,13].

Domotics are slowly becoming a permanent feature in healthcare, but come with risks and challenges too. First of all, the implementation of domotics is complex: there are many different options and applications affect users, healthcare professionals, healthcare processes. and the organization[1]. A dialogue among the various affected stakeholders is necessary. The technology will have to meet the needs of these stakeholders, otherwise it won't work[1,3,4]. Second, the technical infrastructure has to be sufficient and the technological limitations need to be mapped out. For example, while early fall detection is possible, it cannot be prevented from happening. In addition, the detection of an incident or dangerous situation doesn't always mean that help is immediately at hand[1]. Healthcare professionals' suspicion of technology and false alarms actually lead to a higher workload. Personnel will need to be trained and informed about the possibilities and use of domotics[15], a phase that is generally regarded as a big obstacle[16].

The technique will have to support the provision of care and not replace personal attention[1]. Third, the technology itself comes with challenges too. To prevent false alarms, for example, work needs to be done to ensure the accuracy of the systems. Moreover, users are currently required to make a considerable investment, and a balance must be struck between implementation costs and user demands for quality[2,4]. Finally, both the privacy of elderly people and patients and the protection of personal data must be considered[2,4]. The monitored (medical) data must be protected against hackers in order to guarantee secure collection, transmission, distribution, access, and user privacy. Users may have reservations, because of concerns about their privacy[4], although research has shown that elderly people are willing to give up some of their privacy in exchange for more autonomy[17]. Starting a dialogue about this topic is necessary in order to eliminate possible concerns and optimize technological innovations.

Eventually, domotics will become a permanent feature in Western healthcare and essential to promoting the independence of its users and to enabling patients and elderly people to live in their own homes for longer. Thus healthcare costs will be reduced.

Remote monitoring

"There's no technology in telemedicine, or very little, from my point of view, because there's no new data. It's the same doctors making same subjective judgement. Instead of you sitting in their office, they're doing it remotely"

(Hosain Rahman)

Remote monitoring comprises technologies that share real-time (medical) data of individuals with healthcare professionals. The healthcare professional can assess this information remotely and advise the patient if necessary[1,2]. Thus, healthcare professionals can monitor the health of patients remotely. Examples of remote consultation applications are wearable ECG monitors, implanted recorders, pacemakers and insulin pumps. The technology is often used for people with chronic diseases[3].

Remote monitoring can be used to prevent deterioration in chronic diseases and to promote recovery after hospitalization. Patients and healthcare professionals can make informed and timely decisions in the healthcare process and thus improve healthcare quality and patient autonomy[1,4,5]. Remote monitoring reduces the number of hospital (re)admissions, length of stay in hospital, and the burden of care, and it improves the safety, efficiency, and effectiveness of personalized care, along with the quality of life[1,3,5,6]. Ultimately, remote monitoring could lead to improved patient outcomes[7,8] and lower healthcare costs[1,5]. Some say that remote monitoring could help the global healthcare systems cumulatively save a colossal $36 billion over the period 2013-2018 by monitoring patients and timely informing healthcare professionals about possible complications[9].

The remote monitoring market is growing and its value is expected to rise until 2024[4]. There will be a sharp rise in cardiovascular applications in particular[10]. Dutch Minister of Health, Welfare and Sport Edith Schippers stated that by 2019 75% of all people with chronic diseases and vulnerable elderly people should be able to carry out measurements independently in combination with remote monitoring[11].

Tufts UNIVERSITY

Researchers at Tufts University have developed smart stitching that conveys real-time information about wound healing. They integrated nano-sensors, electronics, and microfluidics in the thread, which is able to measure physiological parameters such as pressure, stress, tension, and temperature, as well as pH and glucose levels. Thus the healing process can be monitored and any emerging infections can be detected. More research on smart stitching needs to be done, but it will offer possibilities in the future.

www.tufts.edu

VISIVEST™

The VisiVest™ System, currently only available in the United States, is a vest designed to monitor patients with chronic lung disease and help them with their exercises. When the vest is used during exercise, detailed information about the training is automatically transmitted via Bluetooth to both the user and the healthcare professional. Based on current user data, informed healthcare decisions can be made and therapy adherence is promoted.

www.hill-rom.com

**The value of the global
remote monitoring market 2014-2024**

1.7bn

0.6bn
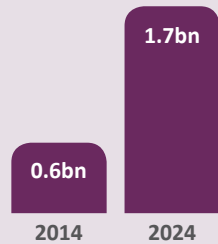
The value of the global remote monitoring market is expected to reach 1.7 billion USD by 2024, at a compound annual growth rate of more than 12% from 2014 onwards[4].

2014   **2024**

Medtronic

The MyCareLink Smart™ Monitor is a remote monitoring system that enables users to share real-time data from their pacemaker with their healthcare professional. Through the use of a mobile scanner, paired with a smartphone app, data from the pacemaker is automatically and securely uploaded. Thus potential complications are detected sooner, patients can avoid some doctor visits, and patient outcomes improve.

www.medtronic.com

However, the latest research shows that so far remote monitoring only takes place on a limited scale[12]. In Belgium and England, initiatives have been launched to use remote monitoring on a wider scale throughout these countries[13,14].

Factors driving market growth are:
- Demographic developments such as an ageing population, increasing life expectancy[15], and growing incidence and prevalence of people with chronic diseases such as diabetes and cardiovascular diseases[16] drive the demand for remote monitoring[1,4,10,17,18].
- Healthcare costs are still on the rise[10,18] and increasingly governments are promoting the implementation of remote monitoring in order to control healthcare costs[1,4]. For example, government policies in the Netherlands aim to enable people to live independently in their own homes for longer[19].
- There is a growing demand for autonomy and independence in Western society[4]. In addition, there is a growing awareness among patients and healthcare professionals of the possibilities remote monitoring can offer in this context[1,10].
- Technical progress and technological developments such as the Internet of Things, smartphones and improved connectivity enable wider implementation of remote monitoring. The technology is getting smaller and more reliable, and can even be implanted in the body[1,4,17].

Remote monitoring is expected to experience strong growth, but there are obstacles too. Professionals may resist the implementation of the technology[1,10]. They will have to be well trained and informed about the possibilities and the use of remote monitoring.

Implementation should serve a clear goal, and possible changes in work processes as well as the wishes of healthcare professionals must be taken into account[5,20]. Patients too may not like the idea of having their health monitored on a daily basis[18]. Further more, it is important that patients for whom remote monitoring is considered are selected according to clear criteria and that the care they receive suits their skills and circumstances. Not all patients are sufficiently informed and have sufficient knowledge to manage their own health. Therefore it may be important to teach them health skills[5]. Finally, there are challenges related to the technological aspects of remote monitoring. Data will need to be protected and the privacy of patients guaranteed[10]. For example, there used to be a medical pump that was hackable, which meant it could administer a deadly dose of medication[21,22].

Due in part to technological progress, remote monitoring will become a permanent feature to help meet the changed demand for healthcare and possibly offer a solution for future problems.

Robotic care

> **Some people have concerns about what it means to leave our responsibilities to robots. I think to some degree in every family, you've got siblings who disagree over the care of their parents**
>
> (Jake Schreier)

Robotic care comprises robotics that help healthcare professionals or carers to look after and monitor patients and elderly people. The technology comes in many shapes and sizes, such as care robots that support the process or take over certain tasks, and robots that keep patients and elderly people company: the so-called social robots.

Robotic care can help healthcare professionals lift patients[1], offers a solution for the expected shortage of healthcare staff[2], and eases the burden on carers[1,3,4]. The robots can help with communication and remind people to take their medication on time, to test their blood glucose levels, or to go to their appointment[5,6]. They can help monitor individuals, collect data, and pass on this information to healthcare professionals[3,5]. Robotic care provides company and helps fight loneliness[1,3,5-8]. Robots have endless patience, help maintain people's dignity, and increase their autonomy and independence[1,4,6]. In addition, they can improve a person's mental wellbeing[9]. Ultimately, robotic care improves the quality of life, helps people perform everyday tasks, and eases the burden on carers and healthcare professionals[1,5].

The robotic care market is growing and the number of units sold annually is expected to rise until 2020[10].

Care-O-bot 4

The Care-O-Bot 4 is a care robot that can perform a variety of everyday tasks. Individuals can configure and use the robot for their own particular purpose and it functions as a true mobile robotic assistant. For example, it can help with cooking, cleaning, transport items, and even provide entertainment.

www.care-o-bot-4.de

Buddy

Buddy is a social robot that improves its users' everyday life. Buddy is equipped with the latest technological gadgets and offers many services. He acts as a personal assistant and supports social interaction, education, and care for children and elderly people. He even guards the house when the owners are out. Buddy is built on an open-source technology platform, making it easy for developers to build and add new applications.

www.bluefrogrobotics.com
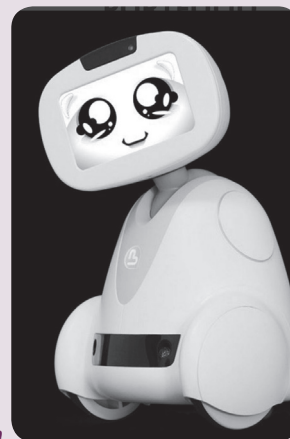
Number of consumer robots worldwide per annum 2015-2020

31.2bn

6.6bn

2015   **2020**

The number of consumer robots shipped worldwide per annum will reach no less than 31.2 million units by 2020. Robotic care is expected to experience further growth and make up a large segment of the market, with 4.5 million shipped units in 2020[10].

RIKEN

Robear is a bear-like care robot designed to aid healthcare professionals. Several sensors and techniques enable the Robear to smoothly perform power-intensive tasks, such as lifting patients out of bed and into their wheelchair. The robot is mobile, can manoeuvre easily through narrow passageways, and is very stable.

www.riken.jp

Factors driving market growth are:
- Demographic developments such as an ageing population[11] and a greater number of people with chronic diseases and with multimorbidity[12] result in greater demand for healthcare. The number of elderly people living on their own has grown significantly in recent years.[13]. Increased healthcare costs[14] and expected healthcare staff shortages[2] drive the search for suitable alternatives to the provision of support and care by healthcare professionals and carers[15-19].
- There is a growing demand in Western society for more personal and better quality healthcare as well as a better patient experience. In addition, there is a growing demand for automation[15]. Furthermore, there is a growing awareness in Western society of the benefits of robotic care and growing acknowledgment that robots can help provide care. People are less dismissive of them, partly because of the younger generations[15,18].
- Technological progress in hardware and software and the rise of artificial intelligence and the Internet of Things drive the implementation of robotic care. Robotic innovations are able to function more and more autonomously. The technology is becoming faster, more efficient, more reliable, and can be integrated with other smart devices nearby due to better IT infrastructures[10,18].

Robotic care is experiencing strong growth, but there are still some hurdles to be cleared. First of all, how will elderly people and patients respond to the technology? It appears that elderly people are generally quite positive about robotic care, although this does depend on their environment and health status[20]. Some feel that the absence of a human relationship is annoying and it is mostly unknown how a social robot will affect family dynamics[21]. Second, healthcare professionals must be properly trained and guided to develop the competences needed to work with the robots and to use robotic care in the most beneficial way[7,20]. However, there are also healthcare professionals who fear for their jobs due to the rise of robots and automation[22]. Third, the costs of robotic care are still high and will further increase due to the required maintenance. Society has to assess whether the benefits outweigh the costs[7,8,21]. Moreover, robots are complex systems and there is still room for improvement of the technology. By integrating artificial intelligence, robotic care will be able to function more autonomously, although this raises ethical issues too. Should a care robot make professional decisions without any intervention by a healthcare professional? And if so, which decisions? Finally, as robots collect and exchange more (individual) data, user privacy must be ensured and legislation put in place[4].

Clearly, robotic care has a lot to offer to Western healthcare and will eventually become a permanent feature in healthcare, supporting consumers, patients as well as healthcare professionals.

What does the future hold?

Healthcare Enablers 2017 gives a sense of the technological innovations that are entering healthcare right now or in the near future. The iconic innovations in this overview are just the tip of the iceberg. The question is not whether they will determine the future of healthcare, but when and how. As enablers, technological innovations contribute to accessible, affordable, and good quality healthcare that will be more personal, preventive, predictive, and – last but not least – more participative.

New technologies enable patients to reach diagnosis at home, consult with a doctor from the comfort of their own living room, and print out their own drugs. Consumers manage their health and collect personal data via online medical portals. Everything is connecting with everything else via the Internet of Things. Augmented reality and robots support healthcare professionals and medical students. And artificial intelligence, big data, nano and gen technology determine diagnoses and treatment choices. Consultations no longer take place between healthcare professionals and patients alone; increasingly often entrepreneurs 'join in' too. They collect and share information and instruct or advise patients.

Digitalization, cheaper technologies, growing personal health awareness, and *power-to-the-patient* are the driving force behind the technological one. '*Cybercare*'[1], '*digital healthcare*'[2] and '*eHealth*'[3] are just a handful of concepts that illustrate the role of technology. Some call it the 'fourth industrial revolution'[4.] It is clear that technology will lead to great changes in healthcare.

Technology is evolving rapidly. However, the success of technologies and their true contribution to the affordability, accessibility, and quality of healthcare depend on many factors. Social and process innovations are needed too, in order to enable technology to contribute to participative, personal, preventive, and predictive healthcare.

This means that informal, formal and self-care are closely intertwined. Technology supports participation of patients, family and carers in the healthcare process. As a result, they are better prepared and able to participate in the decision-making about treatment and healthcare. It also means a personal approach. There is a shift from one-size-fits-all to an individual approach.

The patient immediately receives the most suitable treatment. In addition, the vast amounts of collected information enable us to better predict which people are more likely to develop certain diseases or how they will respond to treatment. Databases and smart software form the basis for research into rare diseases, disease development, and defining optimal treatment. Finally, prevention plays a more prominent role and technology enables greater awareness and behavioural change. Thus, we shift our focus towards staying healthy and preventing disease.

There is certainly no lack of new technology. But the real challenge lies in its implementation. Implementation and acceptance don't always keep pace with each other and there are barriers to overcome, regarding financing, legislation and regulations, standardization, and improving patient safety and privacy, for example[5].

However, the innovation capability of healthcare professionals and healthcare organizations is perhaps most important. This starts with up-to-date knowledge of healthcare technology. Even though the ability to quickly adapt to developments in the outside world, to adopt change, and to translate it to healthcare processes and the organization of healthcare is just as important.

This calls for clinical leadership. After all, the healthcare professionals are the ones who work with patients and other stakeholders to improve healthcare. Day in, day out. It is essential to build a climate for learning and innovation, in which knowledge, capacity, and capital are available to turn plans into action and achieve real renewal. Currently, only a few healthcare organizations have created such an environment. Sometimes, this leads to frustration and cynicism among healthcare professionals who are ambitious about healthcare renewal.

We promise to contribute to the creation of such an environment by spreading knowledge of new technologies in order to help healthcare organizations invest comprehensively in healthcare renewal. Only then will technology quickly find its way to the work floor and contribute to future proof healthcare systems.

Estimated time required for optimal roll-out of innovative technologies in daily practice

The 21 technological trends are heading towards three ultimate goals:
1. Empowered Patient, 2. Bionic Human and 3. Autonomic Systems.

2015   2020   2025   2030   2035

Serious gaming
Holistic tracking — embedded sensors · implantables
Incentivized wellness
Smartfood
Remote consultation
Online social networking
DIY Diagnostics — medical tricorder
Consumer-omics
Domotics

EMPOWERED PATIENT

Digital reality — medical devices · organs & drugs
Printing procedures
Exoskeletons & prosthetics
Nanotech — gene therapy · anti-aging therapy
Advanced labs

BIONIC HUMAN

Internet of Things
Health information systems — data-driven diagnostics
Big Data
Artificial Intelligence
Robotic systems
Remote monitoring — robotic assistants
Robotic care

AUTONOMIC SYSTEMS

Diagnosis Transformation
Transforming Western Healthcare

The Diagnosis programme is ready for the next step. After exploring the future in Diagnosis 2025[1], and innovation-agendas in Diagnosis Diabetes[2] and Diagnosis Healthcare Innovation[3], it is time to bring about change. The future requires us to take a fresh look at health and to organize healthcare in a different way. Small adaptations are no longer sufficient. A transformation is required.

In Diagnosis Transformation, we take stock of the most important trends and developments that impact on Western healthcare. We work on a joint vision of the way the healthcare sector can adapt to provide personal, participative, preventive, and predictive healthcare. The road towards this vision of the future – the transformation – plays an important role. It concerns issues such as: *How do we ensure the strategic adaptability of organizations? How do we increase organizations' capacity to change? How do you deal with barriers in the areas of financing, cultural change, and technology? And how do we introduce innovation into healthcare organizations?*

In this programme, we – together with our strategic partners – facilitate an iterative learning process in order to shape the necessary transformation. The questions and the needs of patients/clients, healthcare professionals, and other stakeholders are the main focus. It is a process in which we share knowledge and know-how regarding transitions, innovations, and changes in healthcare with each other, and put it into practice.

Diagnosis Transformation is a sequel to earlier programmes: Diagnosis 2025 (2010) describes healthcare challenges brought by trends and future scenarios. Diagnosis Healthcare Innovation (2013) was a joint effort by 350 stakeholders to draw up a collective innovation agenda. The Diagnosis network consists of patients/clients, nurses, doctors, administrators, umbrella organizations, knowledge institutes, health insurance companies and other (commercial) organizations. We learn from each other's experiences and work together on a healthcare system that is accessible, affordable, and of a high quality. With Diagnosis Transformation we are taking the next step: from collective innovation to collective implementation.
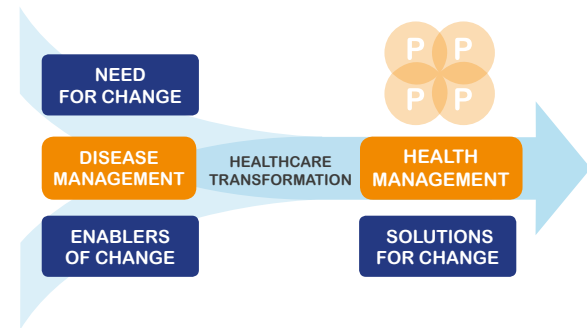
The programme consists of four main activities. First, we conduct a literature review and desk research focusing on the *needs for change* and *enablers of change*. We take stock of the most important trends and developments in Western healthcare. Our first objective is to paint a clear picture of the changing demand for healthcare. The second objective is to take an in-depth look at the technological and social innovations that will fundamentally change our healthcare system. This means that during the second phase, we use case studies to examine successful transformations within and outside the healthcare sector. We combine this knowledge with insights derived from interviews with 'transformation experts', which are conducted during the third phase. Thus we bring the most important lessons of successful (healthcare) organizations into focus. Finally, we verify the models, conclusions, and approaches for transformation during several work sessions with members of our network.

Ultimately, what matters most is the practical application of this newfound knowledge. Therefore, we intend to develop a transformation toolbox that will help and support healthcare professionals and administrators who are working on the necessary transformation within their own organizations. With this programme, we aim to help bring about a transformation of Western healthcare before the need for change becomes too great.

Philip J. Idenburg
Initiator & author

Monique Philippens
Co-author & programme manager

www.diagnoseprogrammas.nl/diagnose-transformatie

Our team

AUTHORS

Philip J. Idenburg

Vivian Dekkers

TEAM DESIGN

Michèle Duquesnoy

Arjo Mans

TEAM STRATEGY

Berend Buys Ballot
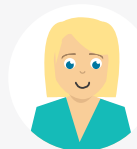
Ellis Boerkamp

Daniel Mogendorff

Joost Kadijk

TEAM RESEARCH

Sjoerd Emonts

Lisa Wekenborg
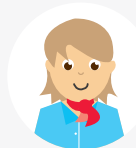
Monique Philippens

Catja Klabbers

TEAM SUPPORT

Karin Rutgers

Sanny Zuiderveld

Romy Smith

Bo Fokkes

About the authors

Philip J. Idenburg MSc. MBA is a managing partner and strategy and innovation advisor at BeBright. In his approach, process and content go hand in hand and must ultimately lead to concrete innovation, as the foundation for the future success of organizations.

Philip is a popular public speaker who has delivered many talks and university lectures. In addition, he has written many articles and books, including 'Oog van de Toekomst', 'Diagnose 2025: Over de toekomst van de Nederlandse gezondheidszorg', 'Diagnose Diabetes', 'Sociaal Wonen 2030' and 'Diagnose Zorginnovatie'.

Besides his experience as an advisor to the Board of Directors of the Rabobank and of KPMG/Nolan Norton & Co, among others, Philip has hands-on management experience at Reed Elsevier, Robeco and Zurich.

Society is currently undergoing a considerable transformation that will put great pressure on existing systems, and on the people and organizations involved. This puts a great strain on managers and administrators, which can only be lessened through leadership and personal transformation. Together with a growing number of administrators and (clinical) leaders, Philip studies the underlying issues that are facing society as a whole and every citizen individually. These conversations take place in the Netherlands and in India, where Philip finds inspiration and regularly recharges his spiritual batteries.

@philipidenburg
www.linkedin.com/in/philipidenburg
philip.idenburg@bebright.eu

Vivian Dekkers is a BeBright consultant who helps clients make strategic choices guided by qualitative and quantitative analyses. Vivian has vast knowledge of all relevant healthcare trends and developments as a result of her involvement in BeBright Analytics and processes such as Diagnosis Healthcare Innovation and Diagnosis Transformation.

In 2012, Vivian conducted research for her thesis 'The Diffusion of Disruptive Innovations in the Dutch Healthcare sector", which contributed to BeBright's Diagnosis Healthcare Innovation. Soon after, she received her Master's degree in Science and Innovation Management from Utrecht University.

Vivian is content-driven and has been collecting information about new technologies for many years. Due to her broad focus on innovation, she is able to translate technological possibilities into concrete healthcare solutions.

She has been applying her wide knowledge to help develop, among other things, the Dutch Hospital Association's (NVZ) vision document 'Healthcare for 2020'. She also helped clients such as De Friesland Zorgverzekeraar, Rabobank and UMC Utrecht deal with a number of strategic issues. She is inspired every day by the possibilities of technology.

www.linkedin.com/in/vivian-dekkers
vivian.dekkers@bebright.eu

www.bebright.eu
www.diagnoseprogrammas.nl

Notes

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HEALTHCARE PHASE 1. PREVENTION & HEALTHY LIVING

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Glossary

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- **3D-printing -** *a production method in which objects are constructed three-dimensionally. It uses materials such as plastics, metals, ceramics, powder, fluids, or even living cells and adds these layer by layer.* **P. 39**
- **3D-bioprinting** - *3D printing of functional tissues and organs.* **P. 39**

A

- **Activity trackers -** *a device that monitors the amount of user's daily moves by counting the number of steps using sensors.* **P. 18**
- **Advanced labs** - *technological developments that lead to new and/or improved (research) techniques and methods.* **P. 47**
- **Affordable Care Act** - *officially named the Patient Protection and Affordable Care Act (PPACA) and nicknamed Obamacare, is a United States federal statute designed to increase health insurance quality and affordability, lower the uninsured rate by expanding insurance coverage and reduce the costs of healthcare.* **P. 15**
- **Ageing population** - *a shift in the distribution of a country's population towards older ages, causing an increase in the population's mean and median ages.* **P. 7**
- **Artificial intelligence -** *a technology that focuses on making machines 'intelligent'. In this case, intelligence is defined as the quality that enables an entity to function properly and with foresight in its environment.* **P. 34**
- **Augmented reality** - *a technology that adds a virtual aspect, audio or visual, to reality. It basically combines reality and the virtual world.* **P. 37**

B

- **Big Data** - *a collective name for very large and complex digital data that is hard (or impossible) to manage with traditional software and/or hardware; nor can it be managed with traditional or usual data management tools and methods.* **P. 32**
- **Bionics** - *replacing or improving organ and/or limb functionalities using technological advancements in humans.* **P. 43**
- **Bionic Games** - *also known as a Cybathlon, is an international competition in which disabled people compete in several disciplines supported by bionic technologies.* **P. 44**
- **BMI** - *Body Mass Index, is a value derived from the mass (weight) and height of an individual. The BMI is an attempt to quantify the amount of tissue mass (muscle, fat, and bone) in an individual, and then categorize that person as underweight, normal weight, overweight, or obese based on that value.* **P. 16**

C

- **Cloud computing -** *a type of internet-based computing that provides shared computer processing resources and data to computers and other devices on demand.* **P. 19**
- **Cloud-powered medical records** - *see patient portals.* **P. 23**
- **Comorbidity -** *the presence of one or more additional diseases or disorders co-occurring with a primary disease or disorder.* **P. 33**
- **Consultation -** *an integral part of almost every interaction between a healthcare professional and healthcare user in the healthcare process, but also between the healthcare user and other healthcare users. A consultation gives healthcare users the opportunity to ask for advice and discuss subsequent steps.* **P. 20**
- **Consumer-omics -** *trend in which it becomes increasingly easy for consumers to have access to information about their own genome, microbiome or metabolome, without any involvement of a healthcare professionals.* **P. 30**
- **Consumer-genomics** – *sequencing and analysis of the genome of a consumer on demand.* **P. 30**
- **Control** - *the verification that treatments and support achieve the desired effect in patients as well as the verification of compliance.* **P. 49**
- **CRISPR** - *Clustered Regularly Interspaced Short Palindromic Repeats, a DNA modification technique for targeted editing of human genes.* **P. 47**
- **Crowdsourcing** - *a specific sourcing model in which individuals or organizations use contributions from an undefined public to obtain needed services or ideas.* **P. 26**
- **Cybercrime** - *crime that involves a computer and a network. The computer may have been used in the commission of a crime, or it may be the target.* **P. 24**

D

- **Deep learning** - *a branch of machine learning based on a set of algorithms that attempt to model high level abstractions in data.* **P. 35**
- **Diagnosis** - *all analysis techniques, procedures and types of research and research results that aim to identify the cause of a health problem.* **P. 27**
- **Digitalization** - *the way in which many domains of social life are restructured around digital communication and media infrastructures.* **P. 7**
- **Digital reality** - *comprises technologies such as augmented reality and virtual reality.* **P. 37**
- **DNA -** *Deoxyribonucleic acid is a macromolecule that carries the genetic instructions of all known living organisms.* **P. 47**
- **Do-it-yourself diagnostics** - *technological innovations that offer consumers the possibility to analyse their own symptoms or conditions in order to make a diagnosis.* **P.28**

- **Domotics -** *comprise the application of sensors and communication technologies in the home or other living areas to support patient care. We distinguish two types of applications: monitoring and guidance.* **P. 50**

E
- **Electronic patient record (EPR)** - *systems, which are usually medical administrative system, in which healthcare professionals record patient's medical data.* **P. 23**
- **Empowered patient** - *comprises a process in which patients are in control of actions and decisions that may affect their health and wellbeing.* **P. 7**
- **Enabler** - *abilities, powers or resources that contribute to a development or desired outcome.* **P. 7**
- **Evidence-based** - *a concept or strategy that is derived from or informed by objective evidence.* **P. 11**
- **Exoskeleton** - *wearable bionic devices with motorized joints to enable the user to simulate the affected biological joints.* **P. 43**
- **Eyewear** - *a device worn over the eyes to support vision or similar purposes.* **P. 12**

F
- **Food biotechnology -** *the use of organisms or parts of organisms in technological processes in the development of foods.* **P. 17**
- **Food scanner -** *devices that are used to identify the ingredients of food products.* **P. 17**
- **Fork serving** - *the fork is brought from plate to mouth.* **P. 16**

G
- **Genetic modification** - *the manipulation of an organism's characteristics, by changing the genetic makeup*. **P. 47**
- **Genomics -** *an interdisciplinary field of science focusing on genomes and its relation and effects towards organisms.* **P. 30**
- **Guidance -** *stabilizing or activating a person's mental, social and physical performance.* **P. 36**

H
- **Healthy living** - *an individual's own behaviour and responsibilities to live a healthier life.* **P. 9**
- **Hearable -** *advanced in-ear devices designed for a broad range of purposes.* **P. 12**
- **Health information systems -** *comprises several information systems, such as electronic patient records, personal health records, and patient portals.* **P. 23**
- **Health Information Technology for Economic and Clinical Health (HITECH) Act** - *act in the United States to promote and expand the adoption of health information technology.* **P. 24**
- **HealthValueCycle** - *In the HealthValueCycle the central focus is on the individual and the healthcare process has a cyclical character. The cycle consist of five phases that all form part of the (generic) care process.* **P. 7**
- **High-end devices -** *devices providing users with the highest possible output quality.* **P. 11**

- **High-throughput techniques** - *advanced technologies that enable users to perform complex processes and expanding the amount of data gathered.* **P. 31**
- **Holistic tracking** - *the collection of personal information about physical, mental, social, and spiritual wellbeing in order to manage individual's own health and make well-informed decisions*. **P. 12**
- **Human Genome Project** - *a scientific research project, launched in 1990 in the US, with the goal of mapping the complete human genome.* **P. 30**
- **Human Microbiome Project** - *a scientific research project, launched in 2007 in the US, with the goal of mapping the complete human microbiome.* **P. 30**
- **Human Metabolome Project** - *a scientific research project, launched in 2007 in Canada, with the goal of mapping the complete human metabolome.* **P. 30**
- **Human-on-a-chip -** *see Organ-on-a-chip.* **P. 47**

I
- **Implantable** – *technological devices being implanted in living human bodies.* **P. 12**
- **Incentivized wellness** - *technique that is used to motivate people to make healthier lifestyle choices and improve their behaviour by offering emotional or financial rewards.* **P. 14**
- **In-silico trial** - *an individualised computer simulation used in the development or regulatory evaluation of a medicinal product, device, or intervention.* **P. 47**
- **Internet of Things -** *a collective name for a network of 'smart' devices that independently exchange data among each other.* **P. 18**
- **Internet of Nano Things** - *the Internet of Things at the scale of nanometres.* **P. 19**

L
- **Lab-on-a-chip -** *a device that integrates several laboratory functionalities on a single chip.* **P. 47**

M
- **Machine-to-human communication** - *the wireless exchange of information between machines and humans.* **P. 18**
- **Machine-to-machine communication** - *the wireless exchange of information between machines and devices.* **P. 18**
- **Metabolomics** - *an interdisciplinary field of science focusing on the metabolome (end products of cellular processes) and its relation towards organisms.* **P. 30**
- **Microbiomics -** *an interdisciplinary field of science focusing on the microbiome (gut flora) and its relation towards organisms.* **P. 30**
- **Microfluidics** - *a multidisciplinary field focusing on the behaviour, precise control and manipulation of fluids and gasses at small scale.* **P. 52**
- **Mindfulness** - *the psychological process of bringing one's attention to the internal and external experiences occurring in the present moment, which can be developed through the practice of meditation and other training.* **P. 38**
- **Monitoring -** *a tool for control, for examining progress, and for reactive compliance.* **P. 49**
- **Multidisciplinary coordinated care -** *various healthcare providers cooperate to optimize patient care.* **P. 21**

- **Multimorbidity - *the co-existence of two or more chronic conditions in an individual.* P. 42**

N

- **Nanotech** - *comprises minuscule technologies varying in size between 0.1-100nm, being applied in Western healthcare.* **P. 45**
- **Next generation sequencing** - *modern advanced technologies that allow sequencing DNA and RNA much more quickly and cheaply.* **P. 31**
- **Nutraceutical** – *any food component that is known to have a beneficial effect on health status.* **P. 17**
- **Nutrigenetics -** *an interdisciplinary field of science focusing on genetic variations and its relation towards nutrients.* **P. 17**
- **Nutrigenomics** - *an interdisciplinary field of science focusing on the effects of foods and food constituents on gene expression and its relation towards human health.* **P. 17**
- **Nutritional genomics** - *an interdisciplinary field of science focusing on the relationship between human genome, nutrition and health.* **P. 17**

O

- **Omics** - *fields of science that deal with themes such as DNA (genomics), gut flora (microbiomics), metabolism (metabolomics), proteins (proteomics) or RNA (transcriptomics).* **P. 30**
- **Online social networking** - *an internet-oriented tool that enables individuals and communities to create and share content, and to engage in social interactions and real-time collaborations. It comprises media such as social network sites, collaborative services, blogs, wikis and virtual communities.* **P. 25**
- **Organs-on-a-chip** - *a multi-channel 3-D microfluidic cell culture chip that simulates the activities, mechanics and physiological response of entire organs and organ systems.* **P. 47**
- **Open-source** - *universal access to a product's design or blueprint*. **P. 39**

P

- **Paramedical care** - *care provided by paramedics, such as speech therapy, dietary advice, physiotherapy, and occupational therapy.* **P. 21**
- **Participative care** - *allowing active participation of patients in their own care*. **P. 7**
- **Patient empowerment -** *see Empowered patient.* **P. 7**
- **Patient portal -** *systematic collection of electronic health information of an individual patient. It is a digital record that can be shared among patients, healthcare professionals, family, etc.* **P. 23**
- **Personalized care** - *see Personalized medicine*. **P. 7**
- **Personal health record** - *a type of EPR used by a patient to maintain and/or manage his or her own health information. The patient may the primary user or even the sole user and may provide healthcare professionals with specific access if necessary.* **P. 23**
- **Personalized medicine -** *care, treatment, and medication are tailored towards patients' needs.* **P. 7**

- **Personalized nutrition** - *the optimal diet being tailored towards the individual.* **P. 17**
- **Person-on-a-chip** - *see Organ-on-a-chip.* **P. 48**
- **Pharmacogenetics** - *the study of inherited genetic differences in drug metabolic pathways which can affect individual responses to drugs.* **P. 30**
- **Pharmacogenomics** - *the study of the role of the genome in drug response.* **P. 30**
- **Phase II trial** - *comprises studies that try to demonstrate the clinical efficacy or biological activity of treatments and studies that try to find the optimum dose at which the drug shows biological activity with minimal side-effects.* **P. 45**
- **Phase III trial -** *comprises studies aimed at being the definitive assessment of how effective the drug is, in comparison with current 'gold standard' treatments. These studies are larger in size and more time-consuming compared to phase II trials.* **P. 45**
- **Power-to-the-patient** - *Patients increasingly make their own decisions; self-management and patient choice become increasingly important.* **P. 8**
- **Precision Medicine Initiative** - *a research project in the US that aims to make advances in tailoring medical care to the individual*. **P. 31**
- **Preconception screening -** *DNA-testing to look for hereditary diseases before pregnancy.* **P. 30**
- **Predictive care** - *care that entails predicting the probability of disease and instituting preventive measures in order to either prevent the disease altogether or significantly decrease its impact upon the patient.* **P. 7**
- **Prevention** - *to ensure that people stay healthy. It has a universal approach: improving and protecting health. But it can also be selective, deemed necessary, or disease-related: preventing illness and complications or detecting them early. Prevention is associated with health promotion initiatives by the government, employers, educational institutions or healthcare organizations.* **P. 9**
- **Preventive care -** *see Prevention.* **P. 7**
- **Prosthetics** - *artificial devices that replace a user's body part.* **P. 43**
- **Proteomics** - *an interdisciplinary field of science focusing on the proteome (the entire set of proteins, produced or modified by an organism or system) and its relation towards organisms.* **P. 30**

Q

- **Quantum dots** - *artificial light sources that are just a few nanometres in size.* **P. 45**

R

- **Real-time** - *the absence or discernible lag or delay in processes: 'at this moment'.* **P. 18**
- **Remote consultation -** *adding an extra (visual) dimension to the usual means of communication.* **P. 21**
- **Remote monitoring** - *comprises technologies that share real-time (medical) data of individuals with healthcare professionals. The healthcare professional can assess this information remotely and advise the patient if necessary.* **P. 52**
- **Robotic care** - *comprises robotics that help healthcare professionals or carers to look after and monitor patients and elderly people.* **P. 54**

- **Robotic systems -** *comprise robotics that make automated execution of (medical) tasks possible through the integration of a variety of external information.* **P. 41**

S
- **Sequencing** - *determination the sequence of the nucleotides in the DNA.* **P. 31**
- **Serious gaming** - *games that are not primarily designed for the purpose of entertainment but for the purpose of education, training or behavioural change*. **P. 10**
- **Smartclothing** - *clothes which are provided with advanced technologies in order to able to map the health of the wearer.* **P. 12**
- **Smartfood** - *technological innovations that enable consumers to gain more insight into the ingredients and amount of calories their food contains, and into the presence of allergenic or toxic substances*. **P. 17**
- **Socialising the Genome** - *an engagement project, funded by Genomics England, to make the subject 'genome' less complex by making genomics an everyday conversation for people currently unconnected to it.* **P. 31**
- **Streaming video** - *videos that are constantly received by and presented to an end-user while being delivered by a provider.* **P. 33**

T
- **Targeted Sensory Reinnervation surgery -** *procedures focused on enabling amputees to control motorized prosthetic devices and to regain sensory feedback.* **P. 43**
- **The Quantified Self** - *a trend that focuses on the phenomenon that humans are increasingly integrating technology into their lives in order to collect data about themselves and to learn from this*. **P. 12**
- **Transcriptomics** - *an interdisciplinary field of science focusing on the transcriptome; the complete set of RNA transcripts that are produced by the genome.* **P. 30**
- **Translational research -** *research that focuses on converting basic research knowledge into practical applications to enhance human health and wellbeing. Translational research provides the transfer and rapid translation of knowledge and innovative technologies towards diagnosis and treatment for the benefit of patients*. **P. 33**
- **Treatment** - *recovery from physical, mental and social health problems, or avoidance of aggravation of these problems, through medical, behavioural and/or paramedical treatment. It also comprises the facilitation of nursing and care, and anticipating the patient's physical circumstances and tasks he or she will be able to perform.* **P. 36**
- **Turing Test** - *a test, developed by Alan Turing, of a machine's ability to exhibit intelligent behaviour equivalent to, or indistinguishable from, that of a human.* **P. 35**

V
- **Venipuncture** - *the process of obtaining intravenous access, most often performed to obtain blood for diagnostic purposes.* **P. 38**

- **Virtual reality -** *creation of a virtual environment that the user experiences as the new reality. Often, virtual reality lets a person engage in interactions in this new world.* **P. 37**

W
- **Wearables** - *technological innovations that can be worn on the body where they can have different purposes*. **P. 12**
- **Western healthcare** - *healthcare in a group of culturally and ethnically related countries, especially between 1500 and the present, that built up a dominant position in the world. The countries mostly belonging to the richest and most powerful countries in the world and have a great cultural influence and dominance over the rest of the world.* **P. 7**
- **Whole genome sequencing -** *the process of determining the complete DNA sequence of an organism's genome at a single time.* **P. 31**

The following symbols will be used in the text and represent:

★	Definition
◻	Applications and advantages
↗	Market
✚	Driving factors
▦	Risks and challenges

Initiated by

be*bright*

accelerating healthcare

Made possible by
the strategic partners of Diagnosis Transformation

kpn

noaber*foundation*

pinkroccade
HEALTHCARE & LOCAL GOVERNMENT
TSS

PROMEDICO@
Beter voor iedereen

——— and ———

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