Chapter 3

Medicine in the Cybernetic Revolution: Medicine and Medical Technologies as a Breakthrough to the Control over Human Body

In this chapter we will concentrate on describing the current and future transformations in medicine. We will focus on those transformations that are an integral part of this complex during the starting period of the final phase of the Cybernetic Revolution. Where possible we will point out the interconnections of medicine with robotics, cognitive and information technologies.

1. Medicine at the Initial and Modernization Phases of the Cybernetic Revolution

At the initial phase of the Cybernetic Revolution (from the 1950s to the 1990s) there was a rapid growth of medicine as an increasingly important service sector. *At the same time the growing health services constituted the general process of a rapid increase in the service sector, which became the leading sector in terms of GDP in developed countries.*

During this initial phase of the Cybernetic Revolution new directions of medicine emerged while those directions that had emerged earlier reached a certain level of maturity (among them are electroencephalography, electric shock therapy, transplantology, active use of electronics, laser and new methods of diagnostics such as ultrasound, *etc.*). Substantial progress has been achieved in the sphere of child mortality reduction, infertility treatment, gerontology, psychiatry, development of contraceptive methods, and transplantation of organs and the creation of artificial organs, gender reassignment surgery, *etc.* Sport medicine, space medicine and other directions in medicine appeared during this time. On the whole, due to medicine people learned about controlling their bodies and maximizing their health.

To better understand the breakthroughs which took place in medicine during the initial phase of the Cybernetic Revolution, it makes sense to refer to the most prestigious award in the field of science. In the period from the 1930s to the 1980s the authors of discoveries in the field of vitamins, hormones, antibiotics, nervous regulation, enzymes were awarded the Nobel Prize. All of these discoveries began to be used in pharmacology. After 1958 genome researchers were awarded the Nobel Prize.

Medicine in the modernization phase. The period from the 1990s till the present represents the modernization phase of the Cybernetic Revolution.

At this phase the major direction of medicine underwent dramatic changes. In the nineteenth and twentieth centuries many fatal diseases were defeated (cholera, yellow fever, typhoid, tetanus, polio, whooping cough, measles, malaria, diphtheria, *etc.*). It would seem that fatal highly infectious diseases except for AIDS (which is widespread in African countries) have been defeated. At the initial phase of the Cybernetic Revolution the fundamental task was to increase the life expectancy. As a result, when the task was accomplished, the main concern of the last period of the initial phase and the modernization phase of the Cybernetic Revolution became the struggle against the diseases of aged people.

According to WHO, in 2012 the most frequent causes of death in the world were respiratory diseases – 6.2 million (14 per cent), ischaemic heart diseases – 7.4 million (11.1 per cent), stroke – 6.7 million (11.9 per cent), HIV/AIDS – 1.5 million (2.7 per cent) (WHO 2014).

As a result of the Cybernetic Revolution the changes in the general trend in medicine led to the emergence of new pharmaceuticals. One of the peculiarities of contemporary medical development is a constantly increasing production of drugs. For example, in the USA, from 1950 to 2000, the number of firms producing drugs increased more than seven times (Demirel and Mazzucato 2008). By 2006, the production of drugs doubled, and the total global market volume of drugs was estimated at US$ 640 billion, about half of which was accounted for in the USA (Kondratieff 2011). This field remains one of the most profitable fields with a sales profitability of 17 per cent (*Ibid.*). Every year the volume of consumed drugs increases by several percent. Over the last 15 years the revenue of the worldwide pharmaceutical market has increased more than twice.[1]

[1] See URL: http://www.statista.com/statistics/263102/pharmaceutical-market-worldwide-revenue-since-2001/

Now medicine is closely related to biotechnologies (through pharmaceuticals, gene technologies, new materials, *etc.*). The distinctive feature of modern medical science is its 'bio-related trends' – a wide use of approaches based on the methods of molecular and cell biology. Note that the growing importance of medicine is shown in the phenomenon of medicalization. It is expressed in the fact that many aspects of human behavior (especially deviant) and psyche which have never been related to medicine, start to be described in medical terms and require medical observation and intervention (see Yudin 2008).

The process of differentiation of medicine which started many years ago in many branches has intensified. At present there are about one hundred medical branches and relative scientific disciplines. Among others, nanomedicine, biomedicine, stem cell research and generative medicine are declared as formed branches (see Strategy… 2013; Wagner *et al*. 2006; Minger 2006). It is also worth mentioning such new directions as shockwave therapy and control of cholesterol levels. The directions which emerged earlier have been actively developing, for example, those which are related to artificial fertilization, maintenance of pregnancy and obstetrics, *etc.*

At present medicine is highly computerized especially in the field of diagnostics, various automatic control systems have been developed; for example, for the control of breathing, nutrient supply to specific organs, blood pressure, control over the functioning of some internal organs, *etc.* A large range of drugs have been developed which over time decrease in price and become more available to the general public. Surgery connected with the transplantation of organs and the replacement of certain human organs by artificial organs, endoscopic surgery providing operations without incisions, and rehabilitation medicine are all developing rapidly. Surgical methods have become less invasive and require less time for rehabilitation.

The current stage is represented by the prevalence of innovations accumulated over the last decades since most of the latest technologies are based on improvements to previous discoveries and inventions. Starting with the 1980–1990s we observe considerable progress in the struggle against the most common causes of mortality – heart attacks, strokes, orphan diseases and other diseases including hereditary. Significant progress has been made in technologies for diagnosing internal organs and tissues using such methods as X-ray computed tomography, nuclear magnetic resonance introscopy, X-ray photography and others (Mirsky 2010: 19). At present the fastest developing fields of medicine (in its broad sense) are the fight against incurable diseases, implantations, reproductive medicine, gene therapy, pharmaceutics and aesthetic medicine which we will consider below.

On the whole, medicine (supported by both government and private funding) has been a major influence on GDP. The distribution of medical technologies is a very expensive process. Despite that cost, there still has been a steady increase in funds allocated to medicine by the state. Generally, its growth is comparable to the GDP growth rate. But in the developed countries spending on health care per capita is 10–20 times larger than in the developing countries. Taking into consideration the anticipated faster growth rates of GDP in the developing countries and a rapid formation of the middle class there, one can suppose that in general, spending on health care will increase significantly. Ageing of the population together with growing prosperity will lead to a situation where health care spending will outpace the general GDP growth. And this tendency is likely to increase.[2] It is not strange because in the developed countries a significant part of population is involved in medicine. For example, in Germany a number of health care personnel constitute 22 per cent of the total number of employed people while the share of automobile industry is only 2.3 per cent (Nefiodow and Nefiodow 2014). The level of medical development has significant impact on such popular development indicators as the human development index (HDI).

At the same time within the medical sphere some major innovations will reach maturity in two or three decades (some of them even earlier). At present the fastest developing fields of medicine (in its broad sense) are the fight against incurable diseases, implantations, reproductive medicine, gene therapy, pharmaceutics and aesthetic medicine which we will consider below. Medicine is closely related to biotechnologies (through pharmaceuticals, gene technologies, new materials, *etc.*). The distinctive feature of modern medical science is its 'bio-related

[2] One can prove this by the fact that even in the periods of insignificant GDP growth, the expenses for health care increase very fast. In particular, in the OSCE countries in the period of the last crisis (2008) the growth of GDP per capita was very low – 3 per cent (correspondingly in 2007 – US$ 35,855, in 2010 – US$ 36,994), and expenses for health care per capita increased by 13 per cent (correspondingly in 2007 – US$ 3,858, in 2010 – US$ 4,364) [calculated on the basis of World Bank 2012]).

trends' – a wide use of approaches based on the methods of molecular and cell biology. There appeared new perspective directions of biomedicine (see Strategy… 2013) and nanomedicine (Wagner *et al*. 2006). Below we will consider some important trends within medicine. Note that the growing importance of medicine is shown in the phenomenon of medicalization. It is expressed in the fact that many aspects of human behavior (especially deviant) and psyche which have never been related to medicine start to be described in medical terms and require medical observation and intervention (see Yudin 2008).

Development of new pharmaceuticals. One of the criteria of medical development is a constantly increasing production of drugs. In the USA, from 1950 to 2000, the number of firms producing drugs increased more than seven times (Demirel and Mazzucato 2008). By 2006, the production of drugs doubled, and the total global market volume of drugs was estimated at US$ 640 billion, about half of which was accounted for in the USA (Kondratieff 2011). This field remains one of the most profitable fields with a sales profitability of 17 per cent (*Ibid*.). Every year the volume of consumed drugs increases by several percent. Meanwhile, along with the expansion of pharmaceutical production, its efficiency is decreasing and they only suppress symptoms but do not have a curative effect (of only 30–50 per cent). The growth of pharmaceutical production is connected with unification which leads to decreasing efficiency as even well-investigated diseases often proceed individually. The solution to this situation can be individualization of medicine due to genetic engineering.

2. Medicine on the Threshold of a Great Breakthrough

2.1. Two decades before the start of the final phase of the Cybernetic Revolution

As we predict within the medical sphere some major innovations will reach maturity in two or three decades (some of them even earlier). Below we will consider some important trends of medicine.

The development of aesthetic medicine. At present aesthetic and cosmetic medicines are vigorously developing and their main task is to correct defects or alterations which concern the person and improve attractiveness (eliminate wrinkles, provide attractive rejuvenation, different types of face lift, liposuction, body shaping, transplant hair, wide spread of already proven technologies, *etc.*). According to *Forbes*, the global cosmetic surgical and aesthetic medical market amounts to 180 billion dollars (Zhokhova 2011).

One of the highest achievements of plastic surgery is the face transplantation. The first full face transplant was performed in France in 2005 on a woman who was mauled by her dog. Recently, details of the most extensive face transplant performed in March 2012 were presented. The doctors from the University of Maryland Medical Center gave a new face including jaw, teeth and tongue to 37-year old Richard Norris.

During the next two decades cosmetic and aesthetic medicines are supposed to rapidly develop (though it can cause rather serious psychological problems including those connected with individual's self-identification). This will be achieved through the emergence of new technologies, as well as the living standard growth in the developing countries. Along with the new technologies there will be a wide spread of already proven technologies (*e.g.*, diverse types of face lift, liposuction, body shaping, *etc.*). The wealthier a society, the more money people spend on health and beauty. Taking into account the growth of the world middle class, this direction and all types of aesthetic medicine are expected to develop rapidly. Once the new technologies based on the achievements of medicine and genetic engineering have been established, aesthetic medicine will be able to become the correction medicine of the future, whose most important task will be to correct birth defects and acquired defects.

Systemic problems of the Pharmaceutical industry. As we have already mentioned, at present the pharmaceutical industry has made considerable progress.

For example, we observe a rapid development of so called generics which are the drugs whose patent protection on the production is no longer valid. It is supposed that the global market of generics will double in the period from 2010 to 2018 and will reach US$ 230 billion. One can explain such a rapid growth by the fact that the vigorously growing economies of developing countries, like India and China, actively enter this market. Such growth is typical of the modernization phase of the production revolution as well as an opposite tendency which will be described below. In the securities market pharmaceutics also shows rapid growth (Williams 2014).

However, the number of serious systemic problems in pharmaceutics is increasing. In particular, in the recent decade there is a reduction in the amount of officially approved biopharmaceuticals protected by patent. On the other hand, a number of clinical trials of drugs steadily increase (Woollett 2012). Despite the rapid growth of capitalization at the markets of bio-technological (pharmaceutical) corporations in 2013–2015 which resembles a rapid growth of capitalization of IT corporations in the 1990s, the innovation process is slowing down. Many observers note that the expenditures on the new drug development are reduced because corporations have to spend from 1.5 to 3 billion dollars for new drug development and the drug development together with testing takes from 10 to 17 years. Therefore, the number of principally new drugs is not only increasing but on the contrary, decreasing; there are no breakthrough inventions (*e.g.*, Saigitov 2015; Martyushev-Poklad 2015). One of the important reasons of reducing production of biostimulators is strengthening control over their production. And most likely the problem of accelerated production of safe drugs will aggravate in the nearest decades; the solution of this problem can become an impetus for a breakthrough.

It is obvious that mass-market drugs have an important disadvantage: its efficiency is decreasing *and really help only some part of patients (from 30 to 50 per cent).* The growth of pharmaceutical production is connected with unification which leads to decreasing efficiency as even well-investigated diseases often proceed individually. *Prescribing faults also cause serious side effects. For example, according to some data (probably, overestimated), in the period from the late 1990s to the early 2000s, prescribing faults annually* caused more than 100,000 deaths (Null *et al.* 2003: Table 1).

The theory of production revolutions can provide a general explanation of such innovation slowdown in pharmaceutics. The main vector of the modernization phase of the Cybernetic Revolution is a wide dissemination of innovations which have already emerged (in the first stage), their modification and synthesis. Therefore, there can be fewer basic innovations in this period in certain directions than in the previous period (yet they are much more widespread). Besides, the increasing scale of the production revolution causes an intensification of the struggle between ‘conservatives’ and ‘innovators’ with respect to the implementation of innovations, for example, in the field of drug control (as well as in the field of distribution of GMOs and other innovations such as cloning, *etc.*).[3] In such situations it is rather difficult to say who is right: 'conservatives' or 'innovators'. On the whole, such discussions contribute to the search for optimal paths towards progress. On the other hand, one can suppose that in the nearest decades there will be a new burst of innovations and creation of new age cures. At present we observe some attempts to find new directions in the field of pharmaceutics.

Obviously, in the work of pharmaceutical firms such an important characteristic of the Cybernetic Revolution as individualization lacks. It is quite obvious since the considerable expenses for the development of new drugs require huge market for their distribution.

However, there are some precursors of the strategy changing towards individualization. For example, let us consider Christopher Wasden and Brian Williams' model. Pointing to such difficulties as lower reimbursement rates, diminished pools of venture capital, the advent of personalized care and a growing demand for improved patient outcomes, they consider them as a precursor to a hurricane that will batter unprepared companies and fundamentally change how healthcare is delivered and evaluated (Wasden and Williams 2012: 2).

These representatives of innovative business offer a new model in pharmaceutical and medical business which is named 'Owning the disease: A new transformational business model for healthcare'. Their suggestions are based on the experience of IT companies and they propose to turn to consumer-centric disease solutions rather than the traditional R&D department approaches (*Ibid.*).

The basic idea of this model is to combine the opportunity to solve the tasks and problems related to diagnostics and treatment of a certain disease. In other words, the patient gets the full range of services to solve health problems connected with the real (or potential) disease.

> Medical technology companies are changing their focus in three important ways, shifting from selling features to providing solutions; from focusing on silos to a broader systems approach; and from generating profits by increasing volume to winning by delivering greater value. In turn, these strategies are transforming the fundamental business model of medical device manufacturers, resulting in them taking a more comprehensive approach to

[3] Here one can make an analogy with a situation in the seventeenth and eighteenth centuries when different craft restrictions stood in the way of technological progress (and the technological progress bypassed these restrictions). That is why one can suppose that a brand new breakthrough can follow a different pattern.

> their business that compels them to seek to 'own' the diseases or conditions their products are intended to treat. Owning the disease should not be confused with disease management, the early iterations of which evolved during the heyday of managed care but which lacked the connectivity and incentives to effectively understand, monitor, influence, and change patient behavior, as well as support care coordination or overcome the cultural divide between payers and providers (Wasden and Williams 2012: 7).

This approach takes account of such important tendencies of the forthcoming Cybernetic Revolution (which have been mentioned above) as resources saving (according to the authors of the project, the systemic approach allows reducing expenses) and individualization. The clients of medical companies insist on a personalized approach and on the correlation between the payment for treatment and its results but not the number of manipulations. As the company will be paid for the results of the treatment and not for the treatment process, it will be interested in avoiding the treatment and searching for the prevention measures and optimal solutions.

The authors of this work believe that the company which will be able to create a platform for 'mastering the disease', will have many strategic advantages over the competitors.

However, the conservatism of the present pharmaceutical and medical institutions and huge financial interests of very influential forces behind them will certainly obstruct such a transition.

The struggle against incurable diseases, as it was said, is the most important direction of medicine. According to WHO, in 2008 the most frequent causes of death were lower respiratory diseases (11.3 per cent), diarrheal diseases (8.2 per cent), HIV/AIDS (7.8 per cent). Meanwhile, in developed countries the most frequent causes of death are coronary artery disease (12–15 per cent), stroke and other cerebrovascular diseases (8.7 per cent), trachea cancer, bronchus cancer, lung cancer (5.9 per cent). In general, mortality from cancer in developed countries reaches the same level of mortality with coronary artery disease.

With the rapid ageing of population the potential danger of age-related diseases will increase. The present tendency is that with growing life expectancy cancer diseases take first place among diseases. Therefore, the most significant task of medicine will be the struggle against cancer and other age-related diseases. In the nineteenth and twentieth centuries many fatal diseases were defeated (cholera, yellow fever, typhoid, tetanus, polio, whooping cough, measles, malaria, diphtheria, *etc.*). It would seem that fatal highly infectious diseases except for AIDS (which is widespread in African countries) have been defeated. However, at present in many developing countries with tropical climate a multitude of people die from infectious diseases and fevers. Nowadays incurable diseases are the challenge for humanity. It is not surprising that big awards are provided for solutions to these problems.

In the context of the struggle against cancer there are some positive changes connected with the possibility of early diagnosis and increasing percentage of cured people (see below) but the situation has not changed dramatically. It is possible that cancer will not be defeated by the 2030s. Apparently, cancer treatment requires considerable changes. If we defeat this disease, there will appear a strong impetus for a breakthrough in medicine and its transition to a completely new level.

Movement towards self-regulating systems and minimization of interference. We observe the growing controllability of systems in different branches of medicine. Some of them have already reached the stage of real self-regulation. For example, life support systems or artificial organs. Other systems are moving towards self-regulation and they are intrinsically linked to the minimization of traumatization of a patient. For example, in surgery a lot of flexible instruments are used allowing the doctor to be able to perform surgery on the most inaccessible parts of human body with minimal incision. These operations are conducted with the help of endoscopes and video cameras transmitting an enlarged image on the monitor. In order to solve the problem of hand tremor special robots are used to substitute for human hands. Operating such a device, a surgeon controls the smallest movements of the instrument (including the laser, or ultrasound). One can anticipate that in the nearest future a lot of operations will be conducted without human surgeon's participation.

Robots in surgery. Surgical robots is a rapidly developing sector. Robots-surgeons are classified as: assistance functions robots, telesurgical instruments, navigation system, robots for precise positioning, robots for specific surgery tasks (Taylor 1997).

The surgical operations involving robots' participation have a lot of advantages. The surgical robot DaVinci is mostly widespread.

It is a big machine which is equipped with flexible 'hands' – manipulators with a set of surgical tools. A very small incision is made to the patient, therefore surgical operations are not so painful and demand the smaller period of recovery. Robots allow to use all the latest tele-video systems which help doctors to see clearly the operation process much enlarged and in color. The doctor watches the monitor and controls the robot, sitting in the other part of the surgery (in future he can also be in any other city or even country), the assistant watches the robot and the patient. For the purpose of watching the surgery process in full detail HD 3D screens are installed for the patients. Surgeries involving robots' participation are becoming very popular, for example, the medical companies in the USA use the billboards for attracting more clients to these painless fast procedures (Pinkerton 2013).

However, along with the advantages, surgical robots cause serious fears. The doctors from Rush University Medical Center, the University of Illinois and the Massachusetts Institute of Technology provided the data according to which the strong increase in the cases of injuries and fatalities after the operations performed by the robots is observed, from 13.3 cases per 100,000 surgical operations in 2004 to 50 cases in 2012 (*Ibid.*). FDA registered an increase of 34 per cent of the deaths from surgical operations involving robots in 2013, relative to the previous year (*Ibid.*). In 2013 Massachusetts health officials sent an advisory to the state's hospitals urging caution, ‘As with any new technology, care should be taken that protocols are in place to ensure appropriate patient selection and the full explanation of risks and benefits for all surgical options’ (*Ibid.*). The cost of surgical operations involving robots is higher as compared to the ordinary types of surgery and in the USA varies from US$ 30,000 to 50,000. The price of Da Vinci starts from one million dollars. However, in view of significant economy at a recovery stage, it is possible to predict that clinics will prefer to buy robots for the long-term economy and customer engagement (*Ibid.*). Substantial savings can be realized on the skilled work of surgeons. Many clinics may not have the leading surgeons; they will be able to use services of online surgical operations conducted by the leading experts hands.

2.2. Once more about premises for a breakthrough

In the third paragraph of the previous chapter we summed up the reasons according to which the breakthrough in the beginning of the final phase of the Cybernetic Revolution will start in some innovative branches of medicine. Successful conditions for this will entail major investments in medicine: increase in the number of well-off and educated people in the developing countries and middle-aged and elderly people in the World (who particularly are willing to actively spend money on medicine), as well as strengthening of the need for extra labor force and interest of the state in improving the working capacity of elderly people. In other words, the conditions to give an impetus to business, science, and state in order to provide a breakthrough in the field of medicine can be unique and *the formation of such unique opportunities is necessary for the beginning of a new phase of the Revolution!*

One more prerequisite for the beginning of the final phase of the Cybernetic Revolution in the 2030s will become remote medical care which will be well developed by this time and due to which there will also be a leveling of conditions for patients. It means that the quality of medical care services will not be so highly dependent on the qualifications of medical personnel in a particular medical care unit. Even now we are witnessing this process, thus we can say that it will be very strong in the nearest decades and in the beginning of the final phase of the Cybernetic Revolution.

3. The Shifts during the Final Phase of the Cybernetic Revolution

3.1. The developing characteristics of the Cybernetic Revolution

Preliminary ideas about the forthcoming changes in medicine. As we have already mentioned the transition to the final phase of the Cybernetic Revolution will begin in some field of new medicine (which could be closely related to some other innovative technologies) and then step by step will affect other fields. In particular these revolutionary changes will be connected with the formation of systems for monitoring health, supporting the organism and treatment will be performed mainly by the autonomous systems which will be able to function regularly and constantly.

Nowadays the boundary between medical diagnosis and treatment already becomes more and more imperceptible. Diagnostics is a constant necessary measure for disease controlling and drug dosage. During the final phase of the Cybernetic Revolution there will start a breakthrough in medicine. It will be connected with the formation of systems for monitoring health, supporting the organism and treatment will be performed mainly by the autonomous systems which will be able to function regularly and constantly. Besides, due to opportunities of remote medical care, there will also be a leveling of conditions for patients. It means that the quality of services will not be so highly dependent on the qualifications of medical personnel in a particular medical care unit.

A breakthrough in the field of struggle against incurable diseases will occur but the most important – in the field of improving the quality of life and extending the working age. Medicine will also develop in the direction of: a) prevention and propedeutics of diseases; b) controlling the processes of life and elimination of irregularities; and c) maximal account of individual characteristics.

Self-regulation and controllability of systems is manifested in many branches of medicine. Self-regulation will manifest in the fact that treatment, operations and further rehabilitation will be under a fuller control of self-regulating systems. In the future it will be possible to provide certain treatments through special devices, systems, robots, *etc.* It is one of the most important directions which will be realized during the 2030–2050s.

Meanwhile, the emergence of robots also shows the transition to self-regulating systems. The scientists from the Oslo University in Norway by means of 3D-printing invented the self-learning robots which also have 3D printers in their structure and are capable to print the necessary detail (Howell O'Neill 2014). The RoboEarth project is very interesting: it is the Internet for robots in which they record all their operations and can address it if the necessary operation is absent in the installed program. It is the beginning of the collective intelligence of robots (Waibel *et al.* 2011).

Another manifestation of self-regulation will consist in the technological and automated control of processes of human organs (through necessary albuminous compounds, cells, antibodies, activization of immune system, *etc.*). In other words, treatment will become more targeted.[4] The drug delivery systems will change dramatically. Nanotechnology, particularly nanotubes, will probably play the key role in it.

[4] One of the contemporary optogenetic technologies provides a good example as well as a general idea of how this can work. The essence of the technology is that the DNA fragment which codes for special membrane proteins is integrated into the genome. These light-activated proteins (from the light-source implanted in the brain tissue or through transosseous luminescence) can create an ion flow inside the cell and thus lead to its activation (Saigitov 2015).

The radical transformations in medicine will dramatically change the position of a doctor. Which technological innovations will cause such transformations?

At present the tests for important indices can be made without doctors by means of special devices and testers (see, *e.g.*, below the paragraph about the antibodies). On the basis of the test results one can define the norm and abnormalities. According to *Scientific American,* there will appear stamp-size medical devices which, if you apply them to a wound, will carry out the blood test and determine which medicines should be used and then will inject them (Rybalkina 2005: 46). In order to remotely control the patients, the company Applied Digital Solutions developed the device 'Digital Angel' equipped with the self-rechargeable energy. This tiny biochip measures the biological parameters of the body. It is unlikely that such devices will appear in the very near future. Nevertheless, the emergence of such forecasts is quite remarkable as they show the movement towards the development of self-regulating systems.

Due to such technologies a number of functions of a doctor can be performed by the patients. Perhaps, in the near future diagnostics will be transferred to mobile devices on the basis of biochips which do not require the specialists' participation. Already now the centers of the best practice (Centers of Excellence) are developing, *i.e.* the places from where the leading doctors will be performing the operations and consulting the colleagues online (Binder *et al.* 2004). Thus, the profession of a doctor in its current form can lose a number of its present attributes. At present such a metamorphosis occurs in service sector (such as photo service, type setting and page makeup, design, selection of interior, purchase of tourist vouchers, selection of routes, *etc.*). Of course, the profession of a doctor will exist but the number of doctors probably will not grow and in the end of the final phase of the Cybernetic Revolution its number will even decrease. If there is a necessity to increase the number of doctors, it will be difficult to make a technological breakthrough because of problems of training and the costs. Such systems as health monitoring system described below will also affect the positions of a doctor.

Improving the accuracy of treatment is a very important direction which can transform the treatment of diseases into a controllable process. One method that will become accurate is drug delivery to target cells. Here nanotubes, which we will consider in the section on nanotechnologies, will probably play the key role. Other methods include affecting the immune system, correction for genetic disorders, change of the technology of surgical procedures towards less harmful manipulations, *etc.*

Constant health monitoring as a self-regulating supersystem. Nowadays the boundary between medical diagnosis and treatment already becomes more and more imperceptible. Diagnostics is a constant necessary measure for disease controlling and drug dosage. During the final phase of the Cybernetic Revolution there will start a breakthrough in all fields of medical care. Thus, very important direction of self-regulation can be associated with the development of the health monitoring system that will allow early diagnosis and preventing diseases. The key compounds of such devices are biosensors.

Biosensors are a good example of self-regulating systems and development of individualization. These are electronic registering devices which use biological material such as enzymes, cells and antibodies. Biosensors are able to transform biological energy into electric one. At present they are actively used in medicine for different analyses: determination of metabolites and hormone levels, *etc*. Also biosensors are already used which allow controlling the changes in organism during surgery. An example of biosensors used at home is the glucometer, a device used to define the glucose concentration in blood. Biosensors are also used in measuring physical activity. They are applied in production to measure different parameters: the proportions of mixture, concentration of toxins, poisonous gases, *etc.* There is the development of biosensors and nanorobots which, for example, can monitor the spread of viruses in the blood online (Cavalcanti *et al.* 2008).

One can easily imagine that in the future biosensors will be able to become an integral part of human life fulfilling the function of a constant scanner of the organism or of certain organs and even transmitting the information about it to medical centers in case of potential threats or serious deterioration in the state of health. Built-in sensors will allow for controlling and regulating all vital processes, as well as prompting the time of drug intake and their dosage, time of physical activities and required exercises with the account of different circumstances, and recommending the most appropriate diet, *etc.* For sportsmen biosensors are already the instruments of control of their physiological indicators for calculation of physical activities level and probably their capabilities will increase. During surgeries, the biosensors will control necessary parameters and will prompt the surgeon regarding further actions. These programs giving particular recommendations for individuals will become a reality. At the same time, smart computer systems will be able to monitor significant fluctuations of indicators and give recommendations about short- and long-term living habits.

What will these innovations bring: will the consequences be good or bad? Of course, people's free agency will be restricted as sometimes it is more difficult to resist machines than human wishes. At the same time, certain imperatives with respect to health will be formed. In fact, everybody will have his own electronic nurse (just like the children of ancient Greek prosperous citizens had teachers from among the slaves, and the children of nobility of landowners had the teacher from among the servants). By the way, it can be especially important for controlling children and nursing sick people who stay at home. If there emerge some relatively cheap multifunctional robots able to flexibly react to changes then the life of people will become much more comfortable (but in that case their independence will decrease).

Respectively, such mini-systems can be integrated into a large system which monitors a large number of people, for example in medical centers, therapeutic facilities, hotels, *etc.* We have already mentioned the decreasing number of hospitals, and such monitoring and remote online access can significantly relieve hospitals. One can imagine that such systems will be able to detect potentially dangerous situations and quickly respond to critical situations. That is a good example of prognostics and prevention of problems. We suppose that it will take much time to create such systems. Besides, there are complicated ethical and legal problems as regards to such monitoring as there always exists the danger that a watching ‘Big Brother’ will take advantage of this.

Economy and optimization of resource consumption. The achievements in medicine will make a significant contribution to *the optimization of resource consumption*: first, it will increase life expectancy (which is the most valuable resource); and, second, it will increase human health and thus productivity. Optimization of resource consumption will be expressed, for example, in the drugs economy due to the targeted delivery and minimization of interference with the organism. Hospital treatment will be less used as the operations will be more targeted, and the rehabilitation period will be minimal. More people will be treated at home since the development of remote treatment is rather probable when doctors control the indices of a patient online and can make the necessary prescriptions remotely. It could sharply decrease a cost of medical treatment which now is exorbitant one for a great number of people. Saving money (as well as resources) is one of the most important directions for the economy.

Medicine heads for increasing *miniaturization (as one of the economy).* We think that with respect to medicine we can use the term 'miniaturization' in two senses. The first meaning is a trend of constantly decreasing size of instruments to micro and nano size (Peercy 2000). The second one is a trend of constantly decreasing the zone of medical intervention on human organism. For instance, during surgery contact is focused only on the target epidermis layers. For example, some eye operations with the use of laser are aimed at removing tissues only a few microns thick. Such operations require no subsequent rehabilitation.

Growing life expectancy and features of the Cybernetic Revolution. In the 2030–2050s, probably, there will be a breakthrough in increasing the life expectancy. Perhaps, it will increase up to 15 years. The increase of life expectancy and especially preserving the quality of life and the individuals' activity for as long as possible in the context of the abovementioned characteristics of the Cybernetic Revolution means a further development of self-regulating systems, individualization, selection of optimum regimes, huge energy saving (including emotional) and unique experience and world perception. Every person gains invaluable life experience during his lifetime. One can also note that it is an opportunity to preserve the previous generations' experience at the expense of the personal experience of long-livers and personal contact of their descendants with them. It is especially important under the conditions of rapid technological development and as a result the rejection of experience and knowledge accumulated by generation previous generations that one could observe already during the several.

3.2. The forecasts of the development of some medical technologies

Artificial antibodies and growing opportunities to use the immune system. There will never be any universal drug against all diseases. But strengthening the immune system is one of the universal directions which can transform this situation and help the struggle against different diseases. There is a special instrument of the human immune system – antibodies.

Antibodies are the molecules synthesized to fight against certain cells of foreign origin – antigens. The damage done by antigen usually leads to the destruction of foreign organisms and to recovery. Specific antibodies are produced for each antigen. They are produced by special immune cells – lymphocytes, which accumulate and circulate in the blood over the period of a lifetime. Thus, everyone has his own protective system based on the 'history of diseases'. It is one of the most important directions of development of *individualization*.[5] Medicine is always connected with a patient's individuality. However, in the twentieth century there was a tendency towards mass medicine (connected with mass vaccination, preventive examinations, *etc.*). At present there are some signs of transition from mass medicine to personal/individual medicine (in particular, in aesthetic medicine), which is related to the general tendency of the Cybernetic Revolution towards individualization. But individualization to an even greater extent will be manifested when based on the unique characteristics of the organism, one of which is the immune system. Artificial antibodies can strengthen the tendency towards the individualization of medicine.

Scientists have repeatedly attempted to produce artificial antibodies. Various methods were used, the most widespread method was isolating antibodies from the blood of animals but the degree of purification remained low. In 1970, Cesar Milstein and Georges Köhler found the method of producing the antibodies of a certain type, that is of monoclonal antibodies. In 1984, they were awarded the Nobel Prize for this discovery. By injecting the antigens into a mouse and by isolating the antibodies from its spleen, the scientists managed to get separate antibodies which were cloned by forming multiple copies of themselves. However, such cells could exist for a short period, and only via their hybridization with the cancer cells there were produced long-lived self-cloning antibodies – hybridomas. Nowadays a focus of much medical research is into the production of antibodies by other means (Schirhagl *et al.* 2012) and also the creation of chemoreceptors (Dickert *et al.*

[5] Here the notion of individualization refers not to every antibody but to the artificial antibodies specifically created by each individual organism.

2001). Antibodies have already become widely used in pregnancy tests, in the diagnostics of many diseases, in laboratory experiments.

We suppose that during the final phase of the Cybernetic Revolution there will be considerable progress in the creation of artificial antibodies and their acceptance by the organism. There is no doubt that progress in this field will lead to a breakthrough in medicine. The formation of artificial antibodies will play an important role in the prevention and treatment of many serious diseases, they will prevent the rejection of transplanted organs, *etc.* This will help make controlling the course of a disease easier and will help in suppressing the disease and defeating the disease if it is possible. Progress towards the creation and acceptance level of artificial antibodies will mean a significant growth of *opportunities to control processes previously inaccessible for controllable interference and appearing of self-regulating systems for regulation of such interference.*

Control of programmed cell death (*apoptosis*) is one of the promising methods to defeat serious diseases including cancer. The researches into this field have been carried out from the 1960s. They show that some cells often die in strict compliance with the predetermined plan. Thus, the microscopic worm nematode's embryo consists of 1090 cells before hatching but later some of them die and there remain only 959 cells in the adult worm organism (Raff 1998; Ridley 1996). The mechanism of apoptosis is associated with the activity of signaling molecules and special receptors which receive the signal, launch the processes of morphological and biochemical changes, and as a result lead to the cell death.

An opportunity to trigger the self-destruction of the cells provoking the diseases can make the struggle against diseases controllable. Besides, it provides a rapid recovery without long period of rehabilitation which is necessary after surgical intervention, chemotherapy or radiation treatment (it is the example of economy of energy and time for a patient). Also switching off the mechanism of cell self-destruction will help to save an organism from some diseases and, probably, to control the process of ageing. We suppose that during the final phase of the Cybernetic Revolution medicine will be able to make progress in this direction and in the mature stages of the scientific-cybernetic principle of production to control it. In this case similar to the artificial antibodies and the systems of immune production (see about it below) the movement towards creation of self-regulating systems will occur on the basis of the influence on the key elements of these subsystems of the organism in order to select the optimal regime in the context of certain goals and tasks. So in some cases it will be possible to evoke the death of unwanted cells deliberately and in other cases to block the mechanism of death of necessary cells.

Breakthroughs in the field of control of human body. Transplantation: on the way to biotechnical systems of the highest level. Another important direction of medicine is connected with the regeneration and transplantation of organs and parts of the human body. At present such operations are already performed, for example, heart, lungs, liver, pancreas, and kidneys are now transplanted. However, human donor organs are scarce, and people who distribute donor organs without special agreement are brought to criminal responsibility all over the world. The solution to the problem of shortage of organs is carried out in different directions:

1. Use of a part of a donor organ and growing a new organ using stem cells.
2. The possibility of xenotransplantation (transplantation of animal organs into humans).
3. The development of different organ substitution technologies such as 3D printers (the most promising direction).

Besides, in medicine scientists already use or work to design different artificial organs: skin, retina, trachea, vessels, heart, ear, eye, limbs, liver, lungs, pancreas, bladder, ovaries. Even combination of the above-mentioned opportunities is rather possible. There is already an opportunity of tissue engineering. In laboratories they cultivate healthy skin or cartilage cells to replace injured bone or cartilage.[6] The potential of this technology is the formation of cell therapy and methods to regenerate tissues.

A breakthrough in medicine has become the development of artificial cornea by the scientists of Stanford University (USA). Such a great achievement became possible due to joint researches in the field of chemistry, nanotechnologies, biology and medicine (which are typical of complex technologies of the Cybernetic Revolution).

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[6] Having grown a sufficient number of cells, these cells are implanted in the developed materials on the basis of polysaccharides and special substrates which control this growth. The growth conditions of the cells in these structures are very similar to their natural environment.

We can forecast that the finding of the opportunity to 'deceive' the mechanism of immune suppression of foreign cells will be the breakthrough in the field of regenerating and transplanting organs and tissues (see above). Already some steps have been made in this direction. Here one can also point to the opportunity to control processes by affecting the key elements of initial subsystem of human organism, in this case switching off the most vigilant systems of immune protection (just like anesthesia during a surgical procedure). The important event was when Japanese scientists discovered a way to reprogram the functions of cells. For example, the skin cells were reprogrammed and substituted for the damaged cells of an eye. Such kind of cells are not rejected, so this direction is exceptionally promising (Kostina 2013).

Neural interfaces and cyborgization. How far can it proceed? As we point out in the Introduction it is obviously that many achievements in medicine will impel our civilization to the state in which more and more humans can become partial cyborgs. Thus, we are following the path of development of self-regulating systems of a new type which will be constituted by the elements of different origin: biological and artificial. All that we have written about artificial organs and tissues will contribute to the breakthrough in the field of production of absolutely new materials which will expand the implementation of non-biological elements in the human body. Thus, the Cybernetic Revolution is closely connected with the process that can be designated as cyborgization. People with disabilities can make the most of the development of medicine and cyborgization as they will be able to significantly compensate their drawbacks.

A popular word 'cyborg' (short for 'cybernetic organism') derives from the word 'cybernetic'.[7] At present the term cyborg is often applied to an organism that has restored function or enhanced abilities due to the integration of some artificial component or technology that relies on some sort of feedback.

Neural interfaces provide new opportunities for the partial cyborgization of disabilities. The technologies creating the interaction between an

[7] The term 'cyborg' was introduced by Clynes and Kline in connection with their theory of the expansion of human capabilities to survive in space. They wrote in their article introducing the notion of 'cyborgs': 'Altering man's bodily functions to meet the requirements of extraterrestrial environments would be more logical than providing an earthly environment for him in space ... Artifact-organism systems which would extend man's unconscious, self-regulatory controls are one possibility' (Clynes and Kline 1960: 26).

individual's nervous system and external devices are called neural interfaces (Brain-Computer Interface). They implement the interaction between brain and computer systems that can be realized via electrode contact with head skin or via electrodes implanted into brain. The implementation of neural interfaces is already wide-spread. They have developed neural interfaces that allow prosthetic devices to be moved via brain signals. Today, there have been developed scanning techniques to study brain signals. This gives an opportunity to reproduce any brain response.

At present there already exist devices which allow paralyzed people to speak, write and even work at the computer as, for example, in the case of the famous astrophysicist, Stephen Hawking. The neurosurgeons from the University of Pittsburgh School of Medicine performed a miracle when they implanted a chip in Tim Hemmes's brain. Being paralyzed, he can move a bionic prosthesis with his mind. The prosthesis has a special computer which conducts the neural impulses from the brain to the specified action (Pylyshyn 2003). Global media actively discussed the news about the attaching of the electrical prosthesis by Italian and Swedish surgeons to a 22 year old drummer Robin Ekestam who lost his arm as a result of cancer. We will continue the discussion on neural interfaces in Chapter 6 below.

Thus, we should be aware of the fact that these technological achievements actually mean not only the formation of a new direction in medicine, but also the moving towards *cyborgization* of a human being and the creation of transcybernetic systems (that is the systems combining elements of different nature). Of course, this can cause a certain and quite reasonable anxiety. On the other hand, expanding the opportunities for not just a long but also an active life is hardly possible without significant support for the sensory organs and other parts of the body which weaken as a result of ageing and other reasons. Finally, contact lenses, artificial teeth, tooth fillings, bones, aerophones, artificial blood vessels, mitral valves, *etc.* allow hundreds of millions of people to live and work and these people still remain humans. The same is true with respect to more complex systems and functions.

However, we think it to be just pure a fantasy the idea that someday the human body will be fully replaced by non-biological material and only the brain or the organs which support the senses (see Introduction; the well-known ideas about such future for humankind are presented by Kurzweil [1999]; see also in Rybalkina 2005: 333). This will never come true. People who propose such solutions, for example, to replace supposedly less lasting and comfortable biological material by the technological inventions (such as replacement of haematocytes by billions of nanorobots, *etc.*) in their forecasts try to use the outdated logic that was widespread several decades ago in science fiction or scary stories: the replacement of biological organisms with technical ones. The modern logic of scientific and technological progress including the latest achievements in bioengineering shows the movement towards the synthesis of biological forms and technical solutions into a unified system. Technical achievements can hardly replace the biological mechanisms which have been selected for many millions of years. On the contrary, we should follow the path of 'repair', improvement, the development of self-regulation and support of biological mechanisms via some technical solutions.

The human brain is very tightly connected with the body and sensory organs, most of its functions are based on the control of the body that does not imply its full-fledged work outside its biological foundation. The opportunities of science and medicine to replace worn organs will increase but the biological foundations of a human will always exist and must prevail. If one can help the human body by different means including methods of activization of immune system, opportunities of genetics, the methods of blocking or decelerating the process of ageing, *etc.* it is much more reasonable to preserve the human biological foundation. In any case, in the nearest decades in the process of cyborgization quite radical breakthroughs are possible, but nevertheless the process of cyborgization will not go too far.

Improvement of individuals' natural abilities. It is important to note that at present all these technologies aim at restoring individual's lost functions. It does not exclude the future possibility that this direction will provide opportunity to move towards improvement of natural and intellectual abilities beyond the natural bounds. However, in fact this can hardly happen by the end of the twenty-first century. Probably, the process will be similar to the process in the field of plastic surgery which was first created for the repair of damaged tissues but then it became the beauty industry.

Gene therapy is an advanced means of correction of an organism. Gene therapy constitutes a separate direction in modern medicine. A significant contribution to its development has been made by the Human Genome Project, whose aim is to determine the sequence of human DNA (Brown 2000; Stein 2004). However, the path from defining the structure of the genome to understanding its functions is long and this scientific discipline is at the very beginning of its development. The leading countries spend billions of dollars on the researches in the field of gene therapy.

Gene therapy combines a whole range of characteristics of the Cybernetic Revolution including expanding opportunities for *choosing optimum regimes in the context of certain goals and tasks*. Historically gene therapy was aimed at treating hereditary genetic disorders. But at present gene therapy is already considered as a potentially universal approach to the treatment of a wide range of diseases from genetic to infectious ones.

There are two approaches to gene therapy: *fetal gene therapy* when foreign DNA is introduced into the zygote (fertilized egg) or a germ at the early stage of development; thus, it is expected that introduced material will be inherited. The second approach is *somatic gene therapy* when the genetic material is introduced only in somatic (that is non-germinal) cells and it is not transferred to sex cells.

There is another approach – activization of organism's own genes for the sake of full or partial overcoming the impact of the mutated gene. The striking example of such approach is the usage of hydroxyurea for the activation of the synthesis of fetal hemoglobin in patients with sickle-cell anemia and thalassemia.

Gene therapy can become the example of individualization of the technologies and targeted influence on the processes. On the basis of the genetic data the most appropriate treatment will be adapted for individual patients, and if it is necessary the defective genes will be corrected. In addition, the actuation of necessary genes and gene silencing (if necessary) are quite possible. Presumably, gene therapy will manifest itself first of all in sports medicine as, first, it can become a new tool in the attempts of the pharmaceutical companies to avoid the control of anti-doping committee and, second, inherent potentialities become insufficient for achieving the best results in big-time sports.

When choosing the appearance of a future child (color of eyes, skin, *etc.*) gene therapy can be used. In future it might be possible that babies will be born almost by order, these will be 'the perfect babies' (Fukuyama 2002 with cite McGee 1997).[8] In other words, that means that parents will choose desirable features of a child before his birth. So, the geneticists will probably find 'the genes' of such qualities as nobility, aggression or self-assessment and even intelligence and due to this there will be created an 'improved' baby. Such genetic improvement will remind the improvement of face and body by plastic surgery methods. In other words, it will be impossible to make a genius or a champion of any child but it is not excluded that it will be possible to improve his potentialities. Just like at present it is possible to improve the sports and intellectual potentialities via pedagogical technologies and certain conditions. Such improvement to a certain extent will remind the situation of agricultural biotechnology.

Presumably, first gene therapy will manifest itself in sport medicine as enormous investments are made in it and the best minds are engaged in this field (*e.g.*, the average annual salary of a physician in sports medicine is about US$ 200,000). Second, it can become a new method in the struggle of pharmaceutical companies against anti-doping committee. Third, increasing of sportsmen abilities is in great demand in professional sport as innate potentialities are no longer enough to set the record.

Changing human reproductive capabilities is an especially important field of medicine. The number of incurable diseases causing infertility decreases. Nevertheless, the only opportunity for such patients is to use *in vitro* fertilization. Besides, due to the development of medicine there increases a number of women who want to have children after their reproductive age is over (*e.g.*, Annegret Raunigk, a 65-year-old woman from Germany gave birth to quadruplets [McKie 2015]). One should mention the technologies of growing an embryo outside the woman's body. The transplantation of reproductive organs becomes possible.[9] The scientists are developing the artificial womb which can be transplanted to a woman with the damaged womb or even to a man that will radically change the concept of sex (McKie 2002) and will cause new ethical problems. Artificial womb experiments have been success-

[8] It is difficult to say how 'perfect' they will be and what kind of problems will appear as a result of these technologies. For example, the possibility to predict the baby's gender resulted in gender imbalance in China. As a result, there are a disproportionate number of boys. Thus, we agree with Francis Fukuyama, who believes that the future achievements of the 'biotechnology revolution' should be accepted with great prudence (Fukuyama 2002).

[9] See http://www.theguardian.com/science/2014/oct/04/woman-gives-birth-womb-transplant-medical-first.

fully conducted in Italy where artificial womb was grown and transplanted to a woman. In our opinion as a result of the final phase of the Cybernetic Revolution the number of the experiments with artificial fertilization will increase and growing of embryo outside the woman's body will become the reality.

The perspective direction in medicine is slowing down the ageing process. It was very difficult to find the scientific foundation of ageing process but finally it probably became tangible after the invention of the genetic structure of special bodies of the cells which are necessary for division – telomeres. It appeared that every time after the duplication of chromosomes a number of telomeres at its ends decrease. That is one of the reasons why cells are getting old and die when an organism reaches certain age. Perhaps, that is why our bodies get older, though hot debates among the scientists about this issue still take place (Slagboom *et al.* 1994). In 2009, Elizabeth H. Blackburn, Carol W. Greider and Jack Szostak were awarded the Nobel Prize in Physiology or Medicine for the discovery of the way chromosomes are protected by telomeres and the enzyme telomerase from terminal underreplication. It is probable that genetic methods can significantly increase life expectancy. On the processes determining ageing and opportunities to 'fight' ageing also see the monograph by Aubrey de Grey and Michael Rae *Ending Aging: The Rejuvenation Breakthroughs That Could Reverse Human Aging in Our Lifetime*.