# Chapter 4

## Biotechnologies in the Cybernetic Revolution: Biotechnologies and Creation of Self-Regulating Systems

Biotechnology is a broad and multifaceted notion. Until the 1970s the term 'biotechnology' was used mainly for the description of some technological processes in food industry and agriculture. After in vitro-cultured recombinant DNA and cell cultures started to be used in laboratories, biotechnology started to associate with genetic engineering, and at present these two concepts are often used as synonyms. Now, there are known several dozens of definitions of biotechnology (see, *e.g.*, Blinov 2003). There are also official international definitions, for example: 'Biotechnology represents a complex sphere of activity in which new methods of modern biotechnology are connected with the established practice of traditional biotechnical procedures. The basis of this growing knowledge-intensive industry is made by the complex of methods giving a chance to the person to change purposefully the structure of deoxyribonucleic acid (DNA), or genetic material, plants, animals and microorganisms as a result of receiving useful products and technologies' (the UN 1992: ch. 16). We interpret *biotechnology as a range of scientific and industrial methods of producing various stuff by means of using live organisms and biological processes.*

The main directions in modern biotechnology are the biotechnology of food, agriculture, products for industrial and household use, pharmaceuticals and other medical preparations, environment protection against pollution, *etc*.

### 1. History of Biotechnology before the Start of the Cybernetic Revolution

In spite of the fact that biotechnology is a rather new branch, the period of 'traditional' microbiological production goes back to the Stone Age: yeast bread, yoghurt, beer, wine, and vinegar have been used since ancient times. The first scientific foundations of biotechnology were set by

Louis Pasteur who discovered fermentation. At the end of the nineteenth and the beginning of the twentieth centuries the microbiological knowledge which found increasing practical application was actively accumulated. In 1917, the Hungarian engineer Károly Ereky introduced the term 'biotechnology'.

Some scholars (Glick and Pasternak 2002) mark the following periods in the development of biotechnology: 1) until 1917 it was the period of 'conventional' microbiological production; 2) from 1917 to 1973 – the period of laying scientific foundations for modern biotechnology. In addition, this period is subdivided into two intervals: from 1917 to 1940 is in a way an 'incubatory' sub-period when biotechnologies were already actively employed, but generally played no significant role in industry and economy; and from 1940 to 1970 biotechnology already became a noticeable branch of industry; 3) from 1970 to the present is the period of the modern biotechnology, implementation of scientific research results in biotechnological production.

This periodization fits well our concept of the Cybernetic Revolution. Actually, starting from the 1940s and until the 1970s one can speak about a rapid development of biotechnologies within the scientific and information phase of the Cybernetic Revolution. They started to most powerfully develop from the 1970s on the basis of the Cybernetic Revolution.

Biotechnology appeared at the last stages of the industrial production principle along with many other innovative branches. In the late nineteenth and early twentieth centuries there appeared biofertilizers and biological preparations for pest control and combatting plant diseases, production experiments in bioconversion (Volova 1999). There was established the production of acetone, butanol, antibiotics, organic acids, vitamins, feed proteins, *etc.* with the help of microorganisms (Yegorova and Samuilova 1987).

*The 1930s and 1940s were marked by the formation of a background for the transition to the Cybernetic Revolution*. At that time there started industrial production of some vitamins, for example, vitamin C. The production of preparations by means of biotechnological methods increased. The first mass biotechnological production was the production of penicillin which started in 1943. The World War revealed an urgent necessity to organize mass production of cheap drugs, provision and vitamins.

## 2. The Initial Phase of the Cybernetic Revolution

### 2.1. Biotechnology becomes an essential branch of industry

According to our concept, the Cybernetic Revolution (its scientific and information phase) started in the 1950s when *a number of trends that used to be non-systemic in relation to the previous production principle obtained a systemic character*. During this period, biotechnology finally became a rapidly growing industrial sector affecting the whole economy. The biotechnological products were widely implemented. In the first decades after World War II a large-scale production of amino acids, unicellular feed proteins (from oil and paper-pulp industry waste), steroids was organized, and cell culture of animals and plants was mastered. Already from the late 1940s they started organizing mass production of antibiotics which found extensive use not only in medical industry, but also in agriculture for treatment of animals and plants, as bioadditives in fodders. Some highly effective forms of antibiotics were created with the help of mutations. The intact cells of microorganisms began to be widely used for receiving medical substances of the steroid type, large-scale production of vaccines was organized (Volova 1999). The production of pharmaceuticals became a successful and also very profitable business; therefore, capitals and scientific forces flowed there. The quantity of medical supplies received via biotechnological method or the so-called 'red biotechnology' began to increase steadily. Let us emphasize that biotechnology became a powerful support for agriculture, as it provides the production of fodder, additives, vitamins, and fertilizers, as well as the protection against pests. By means of biotechnology people also receive biofertilizers, amino acids, organic acids, alternative energy sources, and utilize biological waste. The industrial biotechnological production became possible also due to a wide implementation of automated processes. As noted above, automation is one of the main characteristics of the initial and intermediate phases of the Cybernetic Revolution.

### 2.2. Fundamental breakthroughs in biotechnologies

The breakthroughs in biotechnologies are connected, first of all, with achievements in the study of transferring hereditary information. In 1953, James Watson and Francis Crick defined the structure of the DNA molecule. It laid the foundation for understanding the role of genetic information and basic opportunities of the purposeful transfer of genes from one organism to another. It opened enormous prospects, perhaps, surpassing the most courageous fantasies, like the ones presented by Herbert Wells in his novel 'The Island of Doctor Moreau'. The further discoveries connected with genome were abundant. But, naturally, it took decades for the discoveries to find their industrial implementation.

The period from the 1970s to the 1990s (the end of the initial and transition to the intermediate phase of the Cybernetic Revolution) were also marked by a tidal wave of advances in understanding of molecular biology.

We will list some of them:

– 1973 – Herbert Boyer and Stanley Cohen laid the foundation of the recombinant DNA technology;

– 1975 – George Köhler and Cesar Milstein developed the technology of getting monoclonal antibodies;

– 1978 – the Genentech Company produced human insulin received by means of E. coli (colibacillus);

– 1981 – the first automatic synthesizers of DNA hit the market;

– 1982 – the first vaccine for animals received by the recombinant DNA technology is permitted in Europe;

– 1983 – hybrid Ti-plasmids are applied for the transformation of plants;

– 1988 – the method of polymerase chain reaction (PCR) is invented.

As a result of the mentioned and other findings the genetic engineering becomes a powerful branch of biotechnology. The qualitatively new level of development of biotechnologies from the 1970s meant that within the frame of the Cybernetic Revolution they already outgrew the opportunities provided by the industrial production principle and started to develop on a new basis. During the last decades of the initial phase of the Cybernetic Revolution (from the 1970s to the early 1990s) biotechnology became already quite a significant industrial branch making a considerable contribution to agriculture (both plant growing, and cattle breeding including veterinary science), food and chemical industry, pharmaceuticals and medicine.

## 3. Biotechnology at the Modernization Phase of the Cybernetic Revolution

The period from the 1990s to the 2000s was marked by a powerful advance in biotechnology as a branch of industry.

Biotechnologies become a rapidly growing sector in which many countries started to invest significant funds. The company Ernst & Young (EY) which over 30 years has been analyzing the biotechnological market recorded a sharp rise of biotechnological industry in 2000. In the period from 2000 till 2005 the global revenue in the field of biotechnologies doubled and reached US$ 50 billion. And in 2013 in the USA, Europe, Canada, and Australia the revenue in the field of biotechnologies was about US$ 100 billion (Glen *et al.* 2013). From 2008 most investments in biotechnologies were made in R&D that is in innovations.

During this period the directions connected with genetic modification that developed in the previous phase became stronger. Organisms are cloned and a number of diseases are treated by means of genetic modifications. Along with production of medicines, bioadditives to feeding-stuffs, *etc*., the production of GMO became a very significant agricultural segment; increasing energy prices caused a rapid growth of biofuel production (which includes GM foods).

No wonder that biotechnologies are considered as the most promising branch which can become the engine of a new innovative breakthrough.

The significance of biotechnologies is proved by a wide use of their achievements in different fields. For example, it can be widely applied in food industry as well as in chemical production (in particular, production of polysaccharides, biodegradable polymers, biocatalysis, and also creation of new materials, for example, bioplastics), energetics, agriculture, municipal service (*e.g.*, in waste recycling), the branches connected with long storage of production, medicine and pharmacology, nanotechnologies, cosmetology, military branch are connected with biotechnology. At last, biotechnologies become common for people who use bioadditives and vitamins, special products in a diet, use certain type of cosmetic products, *etc*.

**Biotechnologies contribute to the development of biosensors.** A biosensor can be generally defined as a device consisting of a biological recognition system, often called a bioreceptor, and a transducer (Ferrari 2006). Different biological materials such as enzymes, cells and antibodies are used in biosensors (Vo-Dinh *et al.* 2001; Rusmini *et al.* 2007). Biosensors are able to transform biological energy into electric one. Thus, biosensor technology combines the achievements in biology and modern microelectronics and it seems to be of utmost importance for combining technical and biological elements for the future self-regulating systems into a single system. There are different types of biosensors. Some of them are devices measuring a limited number of parameters (*e.g.*, blood glucose level); others monitor several parameters at once. At present they are used in many fields including measurement of environmental pollutants. They are especially useful for analyses in medicine, for example, to determine metabolites or hormone levels (see also above about health monitoring in the future). Biosensors enable to control various changes in organism during surgery. An example of home-use biosensors are blood glucose meters. Biosensors are also used to measure physical activity. For sportsmen biosensors are already instruments to monitor their physiological parameters. Hundreds and even thousands of biosensors can be combined in biochips. Biochip is a miniature device, essentially the entire laboratory which can perform thousands of simultaneous biochemical reactions. Biochips help to carry out quick analysis of a large number of biological parameters for different purposes, including diagnosis of cancer, infections, and intoxications (Fung *et al.* 2001). The combination of biochips and nanorobots seems rather promising with respect to the online monitoring of the spread of viruses in blood (Cavalcanti *et al.* 2008).

The prospects of biotechnologies are great. So far they are closely connected with microbiology, and microorganisms are everywhere, and thus, the sphere of application of biotechnologies seems boundless (from space needs to production and processing of mineral resources). Finally, biotechnologies will become one of the main spheres where the final phase of the Cybernetic Revolution and the consecutive epochs will unfold (in the 2030s and 2070s).

## 4. The Characteristics of the Cybernetic Revolution in the Development and Application of Biotechnologies

**Advancing on the way to self-regulating systems**. Already in the 1970s, computers were applied for the automation of biotechnological production. Computers rather quickly ceased to play a secondary role and have become the basis of automation (Zudin *et al.* 1987). Thus, the emergence of such journal as *Computers and Automation* edited by Edmund C. Berkeley was no coincidence in 1961. Lots of devices for biotechnology, especially for DNA processing, were designed with the help of microprocessors. In the modernization phase of the Cybernetic Revolution, a powerful development of ICTs and software has raised the automation in biotechnological production and scientific researches to a new level.

In particular, in course of time factories producing biotechnological products demanded a lesser human participation. This substantially cheapens mass production of medicine and agricultural goods making them more available.

The software for the needs of genetic engineering has been rapidly improved. It is the one of many examples of convergence of different directions within the Cybernetic Revolution. Today experts, without leaving the computer, can select a necessary gene, model its embedding and behavior at transformation. There are devices for automatic purification, cleaning of DNA and division into necessary fragments, transfer of a gene, *etc.* The sequenators (the devices for dividing a chain of nucleic acids into nucleotides and composing them) which used to occupy an impressive part of laboratories today are produced in the form of USB flash drivers and serve an example of miniaturization as well.[1]

It is extremely important that at present we can already speak about implementation of the principles of self-regulation at the genome level. In particular, together with a useful gene, for example, of salt-tolerance in plants (Grinin, Kholodova, and Kuznetsov 2010) scientists build in special genes-controllers – the promotors which launch the necessary gene only under certain conditions (a high concentration of salt in the soil). Thus, there emerges a self-regulating biological system (without direct human participation but controlled by people), which has not existed before and which, however, works in a proper way. In brief, we observe a prototype of autonomous and self-regulating biological systems which, thanks to biotechnologies, will be widely and actively used in the future in almost all spheres of life.

In biotechnologies self-regulation is also widely employed at the level of a cell. For example, the feedback strategies of a substratum and

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[1] See about Oxford Nanopore Technologies. URL: https://www.nanoporetech.com/products-services/minion-mki.

enzyme are used, known as the operon model which brought François Jacob and Jacques Monod the Nobel Prize in 1965.

The achievements of contemporary genetic science and technology demonstrate opportunities of creation of self-regulating biological (and ecological) systems of a rather high level in the future. Already today the genetic modification can change a whole population. Thus, the method of distributing genes via 'decoy' individuals is widely spread. For example, infertile mosquitoes were massively introduced into the wild population. Such an ineffective crossing led to the reduction in a number of insects (Tkachuk 2011; Benedict and Robinson 2003).

**Synthesis of new materials**. In the 1940s and 1970s, one of the main directions was the development of industrial production of already known substances (*e.g.*, vitamins) or their analogues; however, during the same period there appeared stuff which does not exist in natural environment (*e.g.*, Humalog, which is a widely applied synthetic analogue of human insulin [Woollett 2012]). This sequence reminds the history of development of chemistry: at first people learned to produce the known substances, and then artificial materials.

Due to biotechnologies many new materials are produced, for example, bioplastics. The main advantage of this material is that unlike ordinary plastic many bioplastics are designed to be biodegradable. Thus, the bioplastics production contributes to preserving environment by reducing the production of goods from non-renewable resources and cutting the discharge of carbon dioxide into the atmosphere. This is an important step to the creation of self-cleaning ecological systems and preservation of environment. The range of bioplastic products is already very large. From 2000 to 2008, the world consumption of compostable plastics made of starch, sugar and cellulose increased by 600 per cent (Ceresana Research 2011). However, the production of oil-free plastic amounts only one per cent so far. The experts consider that by 2020, the production of bioplastics will make 3.5–5 million tons, but, unfortunately, it will be only about 2 per cent of total production of plastics (Leshina 2012). Despite difficulties, biotechnology brings hope for more non-polluting and renewable production which in the long-term will allow saving resources.

**Individualization in biotechnologies**. Genetic engineering appears to be an especially bright example of individualization which is one of the main characteristics of the Cybernetic Revolution. Individualization in biotechnologies is associated, first of all, with opportunities to change genome and to get new properties of an organism. In fact, in future each individual's identity will be taken into account with respect to the life style, health control, improvement of work of an organism, *etc.* (Perhaps, individualization in biotechnologies will be applied not only to human organism, but for example, to pets – dogs, cats, *etc.*).

Another example of individualization in biotechnology is cloning. Cloning by itself is a very widespread phenomenon in nature. One of the first experiments on cloning was performed by Georgy Lopashov in 1948. He proved that if the cell nucleus of the other species is put into the ovule, the set of genes of an embryo will be the same as of an organism whose cell nucleus is used. Numerous experiments showed that if the nucleus of an adult cell is used, an embryo will be nonviable. The experiments on frogs proved that the cells which are not yet specialized can be used in cloning. Thus, the stem (immature) cells came into use in cloning (Gurdon and Colman 1999). Since then scientists have managed to clone pigs, sheep, cows, dogs and other animals. But these experiments were less successful.

There is full and partial cloning of organisms. Of course, cloning of a whole organism is of greatest interest for public, besides it provokes largest disputes on the need and acceptability of such researches. However, despite famous experiments, especially with Dolly the sheep, cloning will hardly develop in the near future due to serious biological obstacles. It is necessary to point that the results of cloning are strongly exaggerated because of the aspiration for sensation. Dolly the sheep grew old twice quicker than the congeners. As a result, the animal was euthanised. Thousands of experiments were conducted with different animals, including more than a hundred anthropoids, but the positive result has not been achieved so far.

The therapeutic cloning provides much more ample opportunities for development and introduction at the level of commercial production. This type of cloning is described in more detail in the section on medicine.

**Resource and energy saving** is one of the main tasks and outcomes of introduction of biotechnology. The basic opportunities with respect to resources saving are connected with possible influence on the genetic organization of living beings which at present serves the basis for the agricultural ('green') biotechnology which has already become a part of the initial phase of the Cybernetic Revolution. The breakthrough in this area is connected with *totipotency* which is an ability of plants to form a full-fledged organism from a single cell. With the necessary gene transfer, one can make, for example, a variety of potato resistant to Colorado beetle, or reduce the susceptibility to drought, cold and other stresses (Grinin, Kholodova, and Kuznetsov 2010). New agricultural technologies are of great importance for the developing countries. For example, genetically modified and pest resistant varieties of cotton plant and corn demand much smaller usage of insecticides and thus such modified plants appear to be more cost-effective and eco-friendly. The individualization is also noticeable in the animal genetic engineering which develops more slowly, but even today has an enormous value for agriculture and medicine (*e.g.*, by means of genetic engineering it is possible to increase milk production, to improve quality of wool, *etc.*).

**The increase and cheapening of food production** is a global challenge for the humankind taking into account that the population number will continue to increase for several decades (first of all in the poor and poorest countries, in particular in Africa), and reach, perhaps, nine or more billion people (see UN Population Division 2012). Biotechnologies can make a huge contribution to the solution of the problem. Already today biotechnologies has made much with respect to the increase of the overall food production due to the increasing yield, resistance of plants to stresses, adaptation to local conditions through the creation of new genetically modified organisms and improvement of already existing GMOs, production of a significant amount of artificial nutrients, in particular, proteins.

The agricultural ('green') biotechnology which has already been involved the initial phase of the Cybernetic Revolution is based on the technology of genetic modification (see, *e.g.*, Borlaug 2001).[2] GMOs allowed significant reducing of expenses, increasing crop capacity, economies on the refusal from long selection. One of the most widespread and widely discussed methods of genetic transformation is the transition of gene of resistance to chemical herbicide under the trade name

[2] About successes of the Green Revolution in different countries see Wik *et al.* 2008; Pingali 2012.

Roundup (Williams *et al.* 2000; Richard *et al.* 2005). As a result when treated with Roundup, genetically modified plants remain intact but weeds are killed.

Despite various sanctions, the overall production of GMOs is quickly growing in crop farming. Since 2010 the GMO farming area in developing countries surpassed that one in developed countries (Clive 2011). The analysis of the world economic effect of using biotechnological cultures shows the increasing profit thanks to two sources. The first one is the reduction of production expenses (to 50 per cent) and the opportunity to get large crops on the same agricultural areas. The second one is a considerable increase of harvest (in case of removal of restrictions on distribution of GMO World GDP could grow by US$ 200 billion [Kamionskaya 2011]).

The problems connected with GMOs, real and imaginary, demand a special consideration. However, in comparison with the problem of hunger or malnutrition they seem less important. No doubt, that such production will increase (especially the production of biofuel) as it is the only way to solve food problems. The biotechnological production gives cheaper food-stuff, increases productivity in territories which used to be unsuitable for the cultivation of crops. New properties of farm animals and plants considerably save time and expenditures inevitable in the case of long selection.

In general, as it was already mentioned, the achievements in genetic engineering will become one of the most breakthrough directions of the future revolution.

**Biofuel.** Biotechnology can help to produce rather cheap alternative energy sources. One can hardly say that biofuel is something new in the history of mankind as firewood, brushwood, *etc.* have been used from ancient times. But now it is extremely important to note that it is a renewable resource, whose overall production has become large notably thanks to biotechnologies. Now its global production amounts to over100 million tons (mainly, in the USA, Europe and Brazil). Today biofuel makes 10 per cent of all energy output; however, by 2035 its application will probably grow by more than ten times. However, the majority of biomass for biofuel (80 per cent) is from forestry residues (Kopetz 2013). Meanwhile, the aspiration to maintain the ecological balance of the planet and to reduce wood use can strongly affect this source of alternative energy.

## 5. Forecasts of Development of Biotechnologies at the Final Phase of the Cybernetic Revolution

### 5.1. The introduction of new technologies at the modernization phase of production revolutions

The modernization phase of a production revolution is characterized by two major trends: 1) the extensive distribution of new technologies with resulting simultaneous improvements; 2) increasing social tensions and even struggle for necessary changes in some spheres of social life due to the introduction of these technologies. In order for the final phase of a production revolution to begin, the development of technologies during the modernization phase has to achieve a rather large variety and 'density'. Taking into account that biotechnologies are innovative branches, any country which wants to be the leader in this field will have to develop them anyway. Let us point out that international documents accepted by the UN Conference on the environment and development (Rio de Janeiro, June 3–14, 1992) placed their highest hopes on biotechnologies.

Therefore, on the one hand, we will observe a wide diffusion of biotechnologies in our everyday lives: in nutrition, various nutritional supplements, and influence on our body (through various branches of medicine, in particular via cosmetic and individualized treatment of body as, for example, body-builders do), *etc*. There must quickly develop the branches which have already become a reality (*e.g.*, the cultivation of genetically modified plants, affecting the productivity of domestic animals, production of biofuel), as well as the technologies which are less spread today, in particular in the development of biomaterials. On the other hand, such a wide implementation of biotechnologies, undoubtedly, will intensify public, diplomatic and economic resistance to the change of traditions, national features, real or imaginary harm. The movement against cloning, GMOs, computer selection, *etc.* has been already spreading in different countries. Such a reaction is quite natural, legitimate and in many respects useful though it may happen that conservatism will suppress the progress. Just within the framework of this struggle and collisions, they may make the decisions which become important in the long term and will promote achieving some balance as well as give an impetus to the development (let us remember that the ban on the importing of cotton fabrics in England served as a trigger for the development of its own cotton industry which became a cradle for the Industrial Revolution [Mantoux 1929; Allen 2009; Grinin and Korotayev 2015]).

### 5.2. The beginning of the final phase of the Cybernetic Revolution and the development of the scientific-cybernetic production principle

Now, proceeding from the current trends and general logic of the development of the Cybernetic Revolution, it becomes possible to set out *the future developmental milestones in biotechnology* at the final phase of the Cybernetic Revolution (in the 2030s and 2070s). As already mentioned, it can start in a rather narrow sphere, from which the innovations will start distributing and gradually penetrate the new areas.

Certainly, it is very difficult to anticipate the direction and time of concrete discoveries. In spite of a widespread idea about biotechnological revolution in the near future we suppose that at the very first stage biotechnology as an independent direction will play a less important role than medicine. It will be rather an important component of medical technologies, providing breakthroughs in the area of treatment of diseases and regulation or monitoring the organism functions. But, probably, the adoption of biotechnological achievements will make it possible to help an organism successfully overcome certain diseases.

**The achievement of self-regulation within a system without human intervention.** The level of controllability will increase considerably within a number of important systems connected with biotechnologies. Thus, probably, while transforming an organism, they will insert not a separate useful gene (Simon *et al.* 1983), but a whole set of necessary genes which will operate depending on environmental conditions. Such characteristics will be extremely important in the case of climate changes which are quite probable. It will become possible to choose the most optimal varieties of seeds and seedling for a unique combination of weather conditions and territory (the sort of imitation of evolutionary selection via automatic search in databases). Consequently, huge databases of such plant varieties and variations will be created. It is quite possible that in the future the whole process of getting a transgenic plant will proceed without human participation, and thus, it will become self-regulated.

It is possible to assume that by the end of the phase of self-regulating systems (and perhaps, even earlier, *e.g.*, by the 2050s) the agricultural biotechnologies will be already developed to a degree that the very adaptiveness of modified products will allow for a response even to the smallest fluctuations of local conditions. In other words, it will be possible to order producers or collectors to create varieties of plants for individual greenhouses, hotbeds or plots. Farmers will be able to select individual fodder and drugs by means of programs and to order them via the Internet. Also people will be able to invent a houseplant hybrid suitable for their individual interior and to order its production and delivery. Thus, individualization will reach a new level.

The same refers to domestic animals: it will be possible to breed animals with peculiar characteristics within separate breeds of animals (or even by individual order). It is probable that the selection of animals on the basis of genetic engineering will also develop in the direction of decreasing human participation.

**The solution of urban and some environmental problems.** Undoubtedly, some important changes will occur in using biotechnologies for the solution of environmental problems. Here it is possible to assume that biotechnologies will be intruded first of all in the urban ecology. It is necessary to consider that in the coming decades the urban population will increase by 40–50 per cent (see, *e.g.*, NIC 2012). With the pace of development quickening in poor countries the problems of unsanitary conditions, incidences of disease, *etc.* will become very acute. And since different diseases can quickly spread worldwide, the problems of some countries will become problems for all countries. Among the problems which can be potentially solved by means of the development of biotechnologies, there are those related to water cleaning, recycling of waste, liquidation of stray animals (it will be promoted by introducing genes for sterility or something of that kind). Already today the microorganisms for water cleaning are employed; with their help we also get bio-gas from waste recovery. But in the future these and similar problems will be solved through the development of self-regulating systems that will make it possible to solve a number of technological and scientific problems.

Thus, just as in the late nineteenth and early twentieth centuries people coped with mass infections by means of biotechnologies, in the middle of the twenty-first century, the latest biotechnologies, perhaps, will help to solve the most vexing urban problems since at least two thirds of the population will live in cities. But the problem of ecological self-regulating systems, naturally, is not limited by cities; it has to be extended to the cleaning of reservoirs and other ecosystems. The creation of ecological self-regulating systems will considerably reduce expenses and free huge territories occupied by waste deposits, as well as allow breeding fish in self-cleaning reservoirs.

One can assume that an important direction will be the creation of self-regulating ecological systems in resort and recreational territories which will provide the best conditions for rest and business.

**The breakthrough in resource saving.** Biotechnology can help to solve many global issues, for example, to cheapen the production of medicines and foodstuffs including producing and making them in ecologically sound ways that can also keep or make the environment pristine, thereby considerably expanding their production. The solution to global food crises will come in different ways, in particular due to the mass production of food protein whose shortage is perceived in many societies (at present the feed protein for animals is generally produced in this way). Even now there are results based on the production of food proteins or, for example, imitation meat. But so far this production is too expensive. Now a gram of laboratorial meat costs 1000 dollars (Zagorski 2012), but this is part of the usual process from the laboratory to mass cheap production.

**The synthesis of new materials.** The creation of self-regulated and self-operated systems by means of biotechnologies, in particular through genetic manipulations, opens an important direction in the field of new materials with desirable properties (*e.g.*, genetic material). At present genetic engineering is able to create not only certain genes but also entire genomes and even chromosomes. The artificial chromosomes can be inserted and add some new genes absent in the organism (Dymond *et al.* 2011). It potentially allows making substitutes for the natural process feedstock, for example, leather. The respective projects are already developed. For example, the Modern Meadow Company aims at making a revolution in clothing industry by growing leather and other types of animal skin in the laboratories (Zagorski 2012).

The process of creation of biotechnological genuine leather will include several stages. At first scientists will select millions of cells from donor animals. It can be both cattle and exotic animal species who are often killed only because of skin. Then these cells will be multiplied in bioreactors. At the following stage the cells will be mingled in one mass which will be formed in layers by means of the 3D bio-printer. The skin cells will create collagen fibers while the 'meat' cells will form a real soft tissue. This process will take some weeks after which soft and fat tissues can be used in food production. Despite the exoticism and queerness of the above-described method, it is actually very similar to the process of production of artificial furs which made it possible to solve the problem of warm clothes.