Chapter 16

NEW PRODUCTS OF BIOINDUSTRY

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INTRODUCTION

The universal nature of modern science is manifested in the wide use of cell and genetic engineering methods based on the development of molecular genetics, which provides opportunities for the genetic reconstruction of living organisms in the directions desired by researchers. The main goal of research is to obtain the greatest possible variety of organisms through genetic reconstruction, which could be used not only for the production of qualitatively new products, but also for the processing of various organic and inorganic substances.

Humanity is waiting for the creation of such cell cultures, with the help of which it will be possible to manufacture valuable medicines, to fight against a number of hereditary, cancer, cardiovascular and other diseases, to contribute to the purification and improvement of the ecological state of the environment. Obtaining new disease-resistant, highly productive plant forms with improved product quality indicators is particularly promising. The pace of development of biotechnology today can be compared with the impressive progress of computer technology more than 20 years ago, and the impetus for this was the birth of genetic and cellular engineering.

DNA molecules isolated from any organisms can be broken at specific points of individual segments with the help of special enzymes (restriction endonucleases). As a result, DNA fragments are formed, which include individual genes or groups of genes. Using sets of special enzymes (ligases), these fragments can be assembled or "stitched" into specific sequences that represent new recombinant DNA. To obtain a large number of identical copies of such recombinant DNA molecules, bacterial plasmids or viruses, called cloning vectors, are usually used.

Changing the genome at the cellular and genetic levels opens up new possibilities in biology for the creation of new and reconstruction of existing genotypes. As a result of cellular hybridization and immunological research, new methods of immunodiagnosis using monoclonal antibodies have been developed. Monoclonal antibodies, characterized by high homogeneity and specificity, are currently used in the diagnosis and treatment of diseases (for example, malignant tumors). These methods are gaining more and more importance in the diagnosis of plant viral diseases. Monoclonal antibodies can be used in the purification of some chemical compounds, etc. Genetic engineering methods are also widely used to increase the efficiency of microbiological production of enzymes, amino acids, vitamins and other chemicals[1] [2].

It is estimated that the profit from the use of genetically engineered transgenic plants in 2020 amounted to 100 billion dollars. Not so long ago, high hopes for solving the problem of food production for all mankind were associated with the so-called "green revolution". However, this enthusiasm is now being transferred to the area of using new methods of tissue and cell culture, as well as methods of genetic engineering in plant breeding, which allows some researchers to talk about the second green revolution. It should be noted that large corporations, especially in the USA, are investing huge amounts of money in programs using methods of genetic engineering and cell and tissue culture to improve agricultural plants. Moreover, they support the creation of agricultural farms, breeding and seed farms, where new biotechnological methods are introduced, as well as new forms of transgenic plants are created.

In the 20th century, the methods of cell, tissue and organ culture played a decisive role in improving the quality and productivity of agricultural plants, then preference was given to the methods of somatic hybridization and genetic transformation. The combination of methods of embryo culture, haploidy and dihaploidy, somatic embryogenesis, somaclonal variability, cell selection, genetic engineering with traditional methods of genetics and selection helps to improve the quality and productivity of agricultural plants that are economically important for our country. The introduction of tissue culture and genetic engineering methods directly affects agricultural production.

1. "Old" and "new" biotechnology

A significant amount of the products we consume are organic products, which are still manufactured according to the proven technology developed by our distant ancestors over thousands of years. Every year around the world, with the help of microorganisms, approximately 100 million tons of bread and bakery products, 100 million tons of beer, 40 million tons of wine, 10 million tons of pure alcohol, 8 million tons of cheese, 800 thousand tons of vinegar essence, and more than 1 million tons baker's yeast. It is the "work"

[1] Biotechnology and Natural Products: Prospects for Commercial Production Albert Sasson. 1992. 112 p.

[2] Feeding Tomorrow's World Albert Sasson, Unesco. 1990. 814p.

of microbes today that creates gigantic quantities of these products, which have a high value (expensive).

Using ancient biotechnological processes, a person had no idea how and why they function in a similar way. Only our contemporaries, thanks to the achievements in the field of biology, managed to understand the causal relationships in most of these processes. Now it has been studied in more detail which types of microbes can be used for certain purposes, how the microorganisms themselves "function", how their enzymes cause (condition) the most complex transformations of substances in a minimal (cellular) volume.

In contrast to old biotechnological industries, microbes are used deliberately and quite intensively in modern biotechnology: by means of selection, cell fusion and genetic engineering, highly productive strains of microbes have been created, which are thousands of times more productive than their natural "fellows". Moreover, new microbes are created that produce substances of "higher" living beings and humans in large quantities. Microorganisms transformed by genetic engineering methods can even produce substances that do not exist in nature at all. In order to obtain new substances, in addition to microbial cells, biotechnology uses more and more "highly organized" cells and tissues of plants, animals, and humans, which "work" in a nutrient environment outside the body, and, moreover, even individual parts of cells. What components of cells can be most usefully used to transform substances outside cells? Of course, enzymes, these biological catalysts of the cell, which condition, regulate and direct all the reactions that take place in the cell. Due to their tiny size and great efficiency, they are often called "good gnomes" of cells[3].

2. "Good gnomes" in the household

Digestion or utilization of starch and proteins in humans and microbes occurs in the same way, with the help of enzymes. Amylases that break down starch and proteases that break down proteins work in the cells of both. In addition, cells are able to secrete enzymes into the environment. In humans and mammals, enzymes are secreted, in particular, by cells of the pancreas into the intestine. Here, starch and proteins are broken down into their building blocks – sugars and amino acids – and are easily absorbed by intestinal cells. In turn, amylases and proteases released from the microorganism break down starch and proteins directly near the microorganism, and the microbes absorb later "digested from the outside" building blocks.

[3] Бабенюк Ю.Д., Антипчук А. Ф. Мікробілогія Київ. Університет «Україна» 2010. 150с.

Soon after the action of digestive enzymes was discovered, it was possible to isolate the secret – these are substances, including enzymes, that are secreted in the body by the glands of internal secretion – the pancreas of a pig, which in dried and crushed form began to be used for digestive disorders. But if amylases and proteases work so well outside human cells and microbes, why not try to use them for other purposes?

Already in 1907, Otto Rehm, the owner of a small firm, had a brilliant idea. It is known that stains containing protein from sweat, blood, egg yolk or other food residues are removed from fabric (underwear) with great difficulty (quite difficult). Rehm suggested adding a powder obtained from the pancreas of a pig to the usual detergent. When heavily soiled laundry was soaked in this "enzymatic" detergent, a strange effect was obtained – the stains were easily washed off, because the proteases of the pancreas split the protein into amino acid building blocks. This is how a detergent with bio-additives was produced for the first time. But the "biopowder" began its victorious march only 50 years later, when instead of an expensive and not very stable animal enzyme, it was possible to establish mass and cheap microbiological production of similar proteases, mainly Baccillus strains. These Bacillus, unlike most microbes, prefer an alkaline environment. And their proteases work best in an alkaline environment, so they are most active in a soapy solution.

Today, 80% of all detergents produced contain proteases. In 1980, about 50 t of bacterial proteases for biodetergents were obtained all over the world. At the same time, enzymes are contained in detergents in literally tiny amounts – "traces". As a rule, this is a characteristic of the content of impurities in the main substance, impurities in the amount of 10^{-1} – 10^{-3} % – traces, 10^{-3} – 10^{-6} % – microtraces, 10^{-6} – 10^{-9} % – ultramicrotraces. Basically, 1 g of detergent contains 0.1 g of enzyme, which is 0.01, i.e. 10^{-2} %. And even with such small amounts of bio-additive, heavily soiled laundry becomes clean. Detergent enzymes are most active in the temperature range of 40-60 ^{o}C. Thus, they help save energy, which would otherwise be needed to boil heavily soiled laundry. In addition, enzymes are removed from the laundry again during rinsing[4].

In some countries, the protease preparation is also sold as a "softener" of meat (tender jam; from the English Tender – tender). It is sprinkled on the meat a few hours before cooking. Enzymes break down tough muscle proteins of meat and make it tender and juicy. By the way, there are cosmetics for skin care that contain proteases. When using them, the skin becomes fresh and pink. It is clear that such soaps and creams contain very small amounts of enzyme!

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[4] David R. Wessner, Christine Dupont, Trevor C. Charles, Josh D. Neufeld Microbiology. New York. Wiley. 2022. 1024 p.

In the leather industry, proteases of microbial origin are used to remove hair and bristles from leather and for its treatment. Previously, animal feces were used for this it was a rather unpleasant job. And today, the secret of this process was discovered: the beneficial properties of excrement, thanks to which they were used for cleaning the skin and removing hair from it, are based on the fact that the microbes contained in it secrete proteases.

Microbial proteases also "work" in the dairy industry: they break down the milk protein casein, because with the sharply increased demand for cheese, rennet is becoming less and less available. However, genetic engineering methods have already produced bacteria that produce animal rennet in bioreactors. In agriculture, proteases are mixed into animal feed to make it more digestible. Acting with proteases on fish processing waste, you can separate the protein "from the bones" and turn it into a mixture of amino acids – an excellent additive to livestock feed.

The field of application of enzymes that break down proteins is far from being exhausted by the above. It is clear that the prerequisite for this is a powerful biotechnological industry capable of cheaply and in large quantities producing enzymes from microbes. Biotechnologists conduct an intensive search for such microorganisms that produce very active and stable enzymes. As such "workhorses", microorganisms that survive in extreme conditions are the most promising, first of all, in hot volcanic springs, in outflows near ore or sulfur springs, in pools for salt production by the sedimentation method, where sea water evaporates and crystalline table salt remains. , or on the seabed under high pressure. But often it is not even necessary to equip expeditions to distant volcanoes in order to find such "living" microorganisms. In Germany, the Leipzig Institute of Biotechnology found bacteria in "titanium" with hot water that had extremely high activity at temperatures of 75 and 92 ^{o}C.

How do you get enzymes from microbes? When it comes to amylases and proteases, the matter is quite simple: microbes, in particular strains of Bacillus or Aspergillus, are grown on protein or starch mixtures. Later, microorganisms induce increased release into the environment of proteases that break down protein, or amylases that break down starch. After isolation of microbial cells, a mixture of unconsumed nutrients and secreted enzymes is obtained. With the help of centrifugation, heavy molecules, in this case enzymes, are precipitated in the form of a concentrated bottom sediment. They are available to consumers either in liquid form or in the form of dried powder.

3. Enzymes "on tether"

"Digestion" of starch with amylases is used for the industrial production of grape sugar (glucose). Grape sugar got its name from the grape where it was first found. As a building block, it is found in sugar beet, milk sugar and starch. To obtain grape juice, white powder of tasteless corn or potato starch is first mixed in water, a starch paste is made and boiled for several hours. This is done in order to make it easier for amylases to access the optimal areas of interaction in the starch molecule. At a temperature of 35-60 ^{o}C, microbial amylases are added to the starch paste. After a short time, all the starch decomposes into glucose, which remains to be cleaned and dried. But there is one catch in this process: as in the case of detergents, enzymes can only be used once. And this is very unfortunate! After all, they were able to break down much more starch than in this one-time process. But so far it has not been possible to develop a cheap method of extracting enzymes from concentrated sugar solutions for the purpose of repeated use.

And in this connection, in the early 1960s, biotechnologists had a brilliant idea: they decided to attach enzymes to fairly large balls visible to the naked eye in such a way that they could really perform their functions, just like a dog, put on a chain, she can still bark, and if the opportunity arises, she can bite. Such enzymes are no longer mobile, that is, they cannot move freely in the solution. Such fixed molecules are said to be immobilized (immobile). Therefore, the new method of work was called the method with immobilized enzymes.

For example, enzymes can be immobilized by chemical binding to glass or polymer in the case of glass or plastic beads; immobilization of enzymes also consists in the fact that enzyme molecules are included in the pores of polymeric materials. "Escape" of enzyme molecules is impossible in both cases. Balls or porous particles have such sizes that they can easily be separated again from the bioreactor with the help of coarse filters. After a short wash, they can be used again in a new process; moreover, many enzymes become more stable as a result of immobilization, because, being located in the pores of spongy materials, they protect against destruction by "voracious" microbes[5] [6].

Now let's see how immobilized enzymes are used in industry. For example, amylases that break down starch into grape sugar are immobilized on simple glass beads: they are firmly fixed on their surface and in the pores. Such immobilized enzymes (ie, glass beads containing enzymes) are loaded into a large steel column of a bioreactor. Then a purified starch solution is passed through it. Amylases, immobilized on glass beads, break down starch to glucose. A specially installed sieve prevents the balls from leaving the reactor together with the glucose solution. Such a flow reactor can work for

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[5] Пирог Т. П. Загальна мікробіологія: підручник / Т. П. Пирог. К. : НУХТ, 2004. 471 с.

[6] Пирог Т.П. Загальна біотехнологія: підручник / Т. П. Пирог, О. А. Ігнатова. К. : НУХТ, 2009. 336 с.

months until all amylases are completely exhausted (lost during dissolution, destruction, etc.) or until harmful microbes settle in the bioreactor.

Grape sugar is a valuable food product for infants, sick people, even athletes, as it is easily and quickly absorbed by the body. But unfortunately, it has only half the sweetness compared to beet or cane sugar. This is easy to check: dissolve a spoonful of beet sugar in one glass of water, and a spoonful of grape sugar in another, after trying the "vodka" from one and the second glass, you can easily make sure that grape sugar does not give the usual feeling of sweetness at all.

4. Biotechnology for sweet tooth

Caries – the destruction of teeth – is one of the most widespread human diseases, it is a kind of "epidemic" in modern society. The occurrence of caries is caused by the activity of bacteria that feed on the remains of sweet food in the oral cavity. As a result, bacteria form deposits and secrete acids that destroy tooth enamel. Therefore, the most frequent "victims" of caries bacteria are lovers of sweets. You can fight these bacteria by brushing your teeth and strengthening them by taking fluoride, as well as by reducing your sugar intake.

But almost no one shows a desire to give up sweets. Therefore, the search for sugar substitutes, which would not differ from it in taste, and at the same time were significantly less caloric (had less nutritional value), due to which they would not contribute to an increase in body weight in a "sweet tooth", has long been underway. Although the previously discovered sugar substitutes – cyclamates and saccharin – are very sweet, they still do not taste like "real sugar". Cyclomates are salts of cyclamic acid, which, as it turned out, have carcinogenic properties, so they cannot be used in food at all. The search for new substances with a sweet taste continues. This is necessary not only for those with a sweet tooth, but also for millions of patients with "sugar disease" (diabetes), for whom sugar can simply play the role of poison. In addition, unfortunately, the number of overweight people is increasing all the time; very often the reason for this is that they consume too much sugar and fat. Grape sugar, which is formed from starch by amylases, is probably not quite suitable as a sugar substitute because of its insufficiently sweet taste. Therefore, its use will lead to an increase in doses, that is, again to excessive absorption of nutrients.

But in 1957, enzyme researchers found a new enzyme in microbes – glucose isomerase. This enzyme converts grape sugar (glucose) into fruit sugar (fructose). Fructose is 80% sweeter than beet sugar! Therefore, it was worth turning glucose into fructose only with the help of glucose isomerase, so that it would be possible to obtain very sweet sugar from starch. In 1966, Japanese scientists successfully obtained fructose syrup from glucose for the first time. It tasted surprisingly sweet and contained fewer nutrients than beet sugar, but was significantly more expensive. Back in 1974, world prices for beet and cane sugar unexpectedly increased 7 times. After that, many sugar companies became interested in the new syrup almost immediately. But the enzyme was still very expensive. The fact is that microbes did not release it into the environment, like amylases or proteases, and therefore it was necessary to isolate it from the cells of microorganisms, where there is a mixture of thousands of different substances, with great difficulty! Therefore, the researchers immediately decided to immobilize the expensive glucose isomerase, which made it possible to use it repeatedly. In addition, due to immobilization, the enzyme became more stable. So, the production of fructose syrup improved. It was a great achievement! When sugar prices fell again in 1976, fructose syrup was not only sweeter, but also, thanks to various technical improvements, cheaper than cane and beet sugar. The syrup won. Today, with the help of immobilized glucose isomerase, 3 million tons of fructose syrup are obtained annually in the world, which is used mainly for the production of non-alcoholic (refreshing) drinks. Using such an example with fructose syrup, you can clearly understand that the development of a new biotechnological method is not everything. It is necessary that the new biological product be better, or at least cheaper than the previously obtained product, otherwise it will not be successful in the world market[7].

Recently, even fructose syrup has a "biotechnological competitor" – a new sweet substance has been discovered that is 200 times sweeter than sugar. Surprisingly, this new "sugar" is a "mini-protein". Its molecule consists of only two amino acid residues – the building blocks of aspartate and phenylalanine: the substance is called "aspartame". Both "tasteless" (unsweet) amino acids – asparagine and phenylalanine – are produced by bacteria in bioreactors in huge quantities separately and only then, with the help of an enzyme, are linked to each other in a two-link chain. It is this double chain that is the aspartame molecule and has a sweet (sugary) taste. Unlike other sweet substances, such as saccharin or cyclamates, it tastes like "real" beet or cane sugar. So far, aspartame is more expensive than fructose syrup, but if using genetic engineering methods it is possible to force microbes to produce aspartame immediately "in ready form" or to produce both amino acid blocks separately in a cheaper way and in even larger quantities, then it is possible that aspartame will soon " will beat" its sweet "competitors". To sweeten a cup of coffee or tea, the amount of aspartame that, when absorbed by the body, corresponds to the total energy absorbed is enough only 4 J (about 1 cal)!

[7] Ніколайчук В. І. Генетична інженерія: підручник / В. І. Ніколайчук, І. Ю. Горбатенко. Ужгород. 1999. 182 с.

5. Microbes are like seasoning in soup

Amino acids could not only sweeten our drinks, but also improve the taste as a seasoning in our diet. One of the amino acids in the form of its glutamate salt is already in every kitchen today as a seasoning. In Europe, glutamate is still most often obtained from wheat. But the world production, which is 500,000 tons annually, is based almost everywhere on the microbiological method with the help of corynebacteria and brevibacteria! Glutamate is used as a seasoning for soups and sauces. It enhances their piquant taste, moreover, it helps to stimulate the appetite even of domestic animals!

Of course, a more important goal than increasing appetite. production of amino acids by microbes for cheap and complete nutrition of farm animals. Of the 20 different amino acids from which humans and animals build their cells, they are unable to synthesize 8 amino acids and therefore must receive them with food. The amino acid lysine, which is found in very small amounts in cereals, is especially important. Meanwhile, such amino acids as lysine are absolutely necessary for the health of animals and people. When feeding farm animals, 1 ton of lysine replaces 75 tons of grain, 5 tons of fish meal, or 9 tons of soybean meal. Crushed seeds of oil plants are used as meal after extracting fats from them or can be used as concentrated feed for animals.

Over time, more and more new properties of amino acids and proteins are revealed. Yes, Japanese researchers found a "mini-protein", the molecule of which consists of two amino acid residues and which tastes like table salt! One of the glutamate salts is even used to create "amino acid" soap, which forms a gentle foam (resembles the foam of whipped protein) and, thanks to its biological origin, is very well tolerated even by sensitive skin. Moreover, this soap can be eaten!

Along with amino acids, humans and animals also need vitamins. Most vitamins help the cell's enzymes in their work and, like enzymes, they can be reused thousands of times, so they require only tiny amounts ("traces"). But if vitamins are missing for some reason, then enzymes, cells, and, as a consequence, living beings themselves cease to function properly. We absorb vitamins with fruits, vegetables, meat, fish, milk, eggs, etc. But quite cheap vitamins are needed in animal husbandry. Nowadays, with the help of bacteria (Pseudomonas propionic bacteria) and the fungus Ashbya, it is possible, for example, to obtain vitamins of the so-called group B very inexpensively. By the way, the production strains of these microbes produce in comparison with their natural ("wild") "relatives" in 20 000 times more than vitamin B_2 and 50,000 times more than vitamin B_{12}.

Immobilized enzymes are also used for the production of amino acids. Enzymatic processes, like all other biotechnological processes, take place at a temperature not higher than 100 oC, normal pressure and do not require either alkalizing or acidification. Immobilized enzymes are also used when creating new types of antibiotics, resistance to which microbes do not yet exist. They change the structure of well-known antibiotics produced by microbes in certain defined places, after which the enzymes of pathogenic microorganisms, such as penicillin, are no longer able to "recognize" these antibiotics "as microbial poisons" and therefore inactivate them.

In addition, immobilized enzymes are able to selectively decompose toxic substances in wastewater. Hydrocyanic acid and its cyanide salts are extremely strong and difficult to eliminate with poisons that arise in industry as byproducts (the best known is potassium cyanide – potassium cyanide). It was discovered that many plants constantly release cyanide into the soil to protect themselves from pests, but that even in close proximity to plants, this poison is safe for some microbes. Indeed, these microorganisms produce an enzyme that "neutralizes" cyanide hydratase, which rapidly (instantly) transforms poisonous cyanide into a completely harmless product. Based on that, they developed a method in which the indicated enzyme is isolated from lower fungi and then placed in a bioreactor, where it "detoxifies" wastewater containing cyanides[8] [9].

Today, in most cases, enzymes are used to transform substances that proceed in one step, or if these transformations cannot be carried out as a result of a conventional chemical process, or if the chemical process is very complicated or expensive. True, attempts are already being made to develop a technology with sequential "turning on" of several enzymes, similar to how it happens in any cell. But it would be expedient to produce, for example, alcohol from glucose with the help of "sequentially included" immobilized enzymes, since for this it is necessary to use 12 different complex enzymes from yeast cells. Moreover, for this they would need to be separated and cleaned beforehand. Currently, it is much easier and better to do this with undamaged living yeast cells. Is it not possible to immobilize cells as well as enzymes? It's quite surprising that this idea arose only a few years ago – only after enzymes were successfully immobilized – and it turned out, indeed, all this works!

At the present time, there are already large research facilities for obtaining alcohol using immobilized yeast. At the same time, the yeast is included in the porous balls. Glucose easily penetrates through the pores to the yeast, and the alcohol and carbon dioxide formed leave the balls just as easily. Columns of bioreactors with a capacity of 2000 liters are filled with balls. The simplified scheme is as follows: a sugar solution is fed from the top of the column, and alcohol flows from the bottom. The immobilized yeast "works"

[8] Юлевич О. І. Біотехнологія : навчальний посібник / О. І. Юлевич, С. І. Ковтун, М. І. Гиль ; за ред. М. І. Гиль. Миколаїв : МДАУ, 2012. 476 с.

[9] Яблонський В. А. Біотехнологія відтворення тварин: підруч. / В. А. Яблонський. К. : Арістей, 2005. 296 с.

continuously for about 4 months and during all this time they produce 2400 liters of alcohol per day. At this time, in the case of "normal" production of alcohol using free-floating yeast cells in the solution, it is necessary to regularly replace the old yeast with a new batch of yeast every few days.

In the old production method, the whole process had to be started again after a few days – with a new sugar solution, new yeast and in a cleaned reactor. In contrast, the bioreactor with immobilized yeast cells functions for a long time, it is 10 times more productive, and therefore the products will be much cheaper than in the previous method.

An enzyme that cleaves a protein produced in a bioreactor by mammalian cells – tissue plasminogen activator t-PA (from the English tissue plasminogen activator), which cleaves a fragment from another enzyme that circulates in the blood (plasminogen) and thereby gives it the opportunity to actively dissolve the network of protein threads (fibrin), which firmly holds the blood clot (thrombus). Thanks to this, the heart quickly begins to be supplied again with oxygen and nutrients. There is a proposal that already t-PA will help save the lives of millions of people.

6. Genetically modified food products

It is interesting that one of the authors got acquainted with the fruits of genetic biology on 6 hectares of his dacha. When in the spring you bring 5 kg of shriveled potatoes (each the size of a walnut) from the store and try to pass it off as "seed material" – it causes a slight smile. "Potatoes from Belgium," the shopkeeper said, "you won't have to regret it." It was before the May holidays, so the forced experiment began.

They planted "Belgian gostinki" in the ground, there was, of course, no hope for an autumn harvest. But soon some miracles became noticeable. The summer turned out to be rainy, everything rotted on the neighbor's acres, and in our garden, lively and healthy tops grew. But then a fierce enemy appeared – the Colorado potato beetle, but for some reason it bypassed our acres. The tops were not damaged, but some darkened quite early, from which it can be concluded with some caution that the plant gives all its strength to the tubers.

The moment of triumph came in August. Our modest area has never seen such generous gifts! Potatoes – large, selective, 15-20 centimeters long – so many came out of the ground that we ate enough of this product in the garden plot, but also brought potatoes for the winter. It's hard to believe that all this wealth grew from a bunch of May dead bodies (measurements)!

I don't want to state this categorically, but it seems that our miracle potato turned out to be a genetically modified food product (GMO). Such products will not appear in our trade, without all kinds of markings and messages for buyers, which, of course, is a clear mess and disorder. Modern biotechnology makes it possible to produce such things for which humanity is psychologically not ready...

About 20,000 giant salmon swim carelessly in the huge pools owned by the American company A-Ef Protein, unaware of the discussions that are taking place around them. According to company manager Arnold Satterlin, the fish that were exposed to the growth gene completely outcompete their "wild" relatives. They are several times larger in size, gain weight 4-6 times faster, are more resistant to various diseases and reproduce faster.

Although the headquarters of the company is located in the city of Waltham (Massachusetts), the company wisely placed gardens for its underwater heroes on Prince Edward Island in Canada. The fish had to emigrate because the Food and Drug Administration in the United States has not yet given permission to breed super salmon, although experiments with several types of fish – trout, carp, catfish, and shrimp – are being conducted directly in the United States.

The USA is one of the leaders in genetic engineering. Private companies have achieved revolutionary results in the cultivation of GM plants, which have clear advantages over natural "originals", in particular, the ability to resist diseases and pests, withstand low temperatures, high humidity, drought (drying) and other negative natural factors. In addition, modified plants give a much higher yield. All this is achieved by introducing the genes of other plants, bacteria, animals and even ... humans into the genetic code of various cultures[10] [11].

So, fish genes are added to modified corn, and scorpion genes are added to potatoes (not soon, after learning about this, you can remember the miracles in the backyard). Human genes responsible for the immune system are added to some plant crops. The mechanism is as follows: during the development of the recipient, the donor gene changes its structure and endows it with new properties.

Pairs are selected sometimes simply fantastic − at the level of folklore fables. What can be obtained by crossing a hedgehog with a snake? Barbed wire. But tomatoes, which are inoculated with the genes of deep-sea sharks, remain tomatoes, they do not acquire the ability to be stored at room temperature for more than six months and at the same time do not spoil. If desired, you can even grow tomatoes that have a cubic shape. This is successfully done in Israel: "cubes" are easier to put in boxes and transport.

An ordinary ripe melon becomes disgustingly soft (unpleasant) and loses its taste in a few days. GM can be stored for months, remaining a tempting delicacy. Even bananas that have been in the hands of geneticists can be

[10] Biotechnologies: Challenges and Promises Albert Sasson, Unesco. 1984. 328 p.
[11] Biotechnologies and Development Albert Sasson, Unesco. 1988. 361 p.

picked ripe, not green, as is usually done. In addition, GM bananas do not darken, even when they are peeled.

It is not difficult to understand that the set of all these qualities is extremely profitable for the company producing the products, which is why the world is obliged to the rapid distribution of products with gene components. At the same time, the foundations of a completely new direction of genetic engineering are being laid. We are talking about the possibility of such an effect on the animal's body, which makes it a producer of key components of unique medicines.

The famous Plant Institute in Scotland, which was the first in the world to clone Dolly the sheep from the cells of an adult animal, recently announced a new revolutionary project. Scientists began to create a genetically modified chicken, which was named Britney, it will lay eggs, no, not golden, but even more valuable – with proteins that can attack human cancer cells. Anti-cancer substances will be found in egg white, which will allow scientists to obtain them in the necessary quantity to launch a new generation of drugs in the fight against the terrible disease. Today, this type of protein is produced in limited quantities, and the cost of its synthesis reaches unprecedented and unheard of amounts[12].

In general, the advantages of HMPH are more than obvious. Unfortunately, the consequences of their introduction into production practice and consumption are not so well known. Therefore, some British scientists are not in a hurry to recognize the benefit of forcing the production of HMPH and warn that their spread can have harmful consequences for all of humanity. English scientists have already dubbed them "Frankenstein's food", that is, such a creation of man, which is capable of dooming him to death.

In the north of Great Britain, in Scotland, the leaders of the industry, which has achieved considerable success, in the cultivation of salmon for bayonets, met the American experiments in the conveyor production of the "eponymous" giants. "It is impossible not to see the harmful effects of giant fish on natural fellows," says an employee of a fish factory, where 120,000 tons of sweet salmon are produced annually.

American researchers from Purdue University in Indiana, William Muir and Richard Howard, agree with him and looked at the problem from a completely different angle. It turned out that full-bred modified fishes attract 4 times more males than "natural" sisters, which look pitiful against their background. As a result, lucky GM rivals spread their altered genes at the same – four times greater – speed. However, their offspring were not stable enough, which lowers the chances in the fight for survival. It seems that Shakespearean dramas can take place under water.

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[12] Яблонський В. А. Біотехнологія відтворення тварин: підруч. / В. А. Яблонський. К. : Арістей, 2005. 296 с.

"Wild salmon are in serious danger," said Doug Parr, Greenpeace's lead scientific advisor. The consequences of such biotechnological experiments are unpredictable and may prove fatal. According to Greenpeace specialists, they managed to establish that GM corn pollen kills not only insect pests, but also harmless Danaid butterflies. It is unlikely that the general public can be confused (excited) by the fate of some butterflies. But there are other warnings. So, if GM crops begin to cross with conventional crops and produce "superweeds", it will not only deal a blow to farming, but also displace some plant species from the wild. Oats are given as an example, with a wild relative of which it is still difficult to fight. If a genetically engineered, viable, resistant oat shares this property with its wild counterpart, a monstrous monster will emerge (form).

Scientists still cannot answer with 100% certainty the question of whether HMPH is harmless to humans. In June 2000, the first confirmation appeared that food from GM products can cause mutations in living organisms. The German zoologist Hans Heinrich Kaatz proved in experiments that the changed gene of oil turnip penetrates into the bacteria living in the bee's stomach and begins to mutate there. "Bacteria in the human body can also change under the influence of products containing foreign genes," the scientist believes. "It's hard to say what this will lead to. Maybe even a mutation." Not a very fun prospect...

True, there are counterarguments, defenders of genetic engineering claim: Kaats' discoveries prove nothing. It is known that the bacteria living in the human stomach are constantly changing even without the influence of foreign genes. It sounds convincing. But if you try to delve into the disputes of scientists, you can bury yourself under the piles of evidence "for" and "against". Only one conclusion is indisputable: extreme caution is necessary in gene experiments. Permission for the use of new medicinal products is issued only after a thorough multi-year study of their effects on animals and humans. Transgenic products are freely sold all over the world, although they began to be produced only a few years ago. Meanwhile, it will be possible to truly assess their effect on the human body only after half a century.

Perhaps the GM potato bred by the American company "Monsanto" is really harmful only to the Colorado potato beetle, which dies instantly after eating its leaves. But Scottish scientists from Aberdeen, A. Pushtai, after painstaking research, discovered changes in the internal organs of rats that ate Monsat potatoes. Concerned and coordinator of the Russian program "Greenpeace" Ivan Blokov: "It has already been proven that if you eat such potatoes for several months, the stomach begins to produce enzymes that neutralize the medicinal effect of antibiotics of the kanamycin group."

There are more disturbing indications. There is a well-known case when the genetic technology used for the preparation of the sleeping pill

"L-tryptophan" led to the death of several dozen people in the United States, and an even greater number was condemned to disability. The company that produced it, in order to prevent a scandal, paid the victims $2 billion in compensation without much fanfare. But human life is priceless...

Adding fuel to the fire of passions is the fact that the already well-known Monsanto company acted as a pioneer in the practical development of transgenic technologies. Having started to produce HMPH in the late 1980s, it first sold them in the USA, and recently entered the markets of other countries. But there are more strange pages in the biography of "Monsanto". Its well-being rests on the foundation of close ties with the US military-industrial complex. During the Vietnam War, it supplied the American armed forces with chemical weapons – the defoliant "Agent Orange". It was sprayed over the jungle, after which the lush vegetation died, which helped the Americans track down and attack the Vietcong units. In total, during the years of the war, more than 70 million liters of defoliant were sprayed over the territory of Vietnam and more than a million hectares of forest were destroyed, which caused irreparable damage to the environment. More than 2 million Vietnamese were affected by the defoliant, in which this highly toxic chemical caused irreversible changes: the victims' heads were deformed, their hair fell out. And now, more than a quarter of a century later, the highest level of genetic pathologies and a significant number of children with congenital defects have been registered in the areas where Agent Orange was sprayed in Vietnam. People continue to die from diseases caused by the poison chemical.

Perhaps it would not have received such publicity if only the Vietnamese were affected by the defoliant. But American soldiers also got it, and they don't like it very much in the USA. A terrible scandal broke out. The government commission, having conducted an investigation, found out: the company "Monsanto" hid that the composition of "agent orange" included dioxan – a substance that causes gene mutations. Thanks to the efforts of the military and the company's management, the scandal was hushed up, and the terrible consequences of the use of the defoliant were declared "unpredicted side effects" (among other things, very similar to the term "side effect", which is widely used in NATO during the bombing of Afghanistan, Yugoslavia and other countries). The ominous paradox of this tragic story is that it was the results of "experiments" during the Vietnam War that allowed Monsanto specialists to break ahead in the creation of GM plants. Now "Monsanto" is a large, one of the largest suppliers of transgenic products in the world. The company employs 25 thousand employees, thousands of them are scientists. She has the strongest lobby in Washington. Former President Jimmy Carter is among the company's official consultants. At one time, during a visit to

London, President Bill Clinton even appealed to Prime Minister Tony Blair to allow Monsato to begin planting its oil and other GM crops in England.

In general, transgenic technologies have a certain diabolical aura. But, despite the completely legitimate fears of scientists and ecologists, commercial and political aspects play a significant role in its creation. The fact is that the founders of the new technology were the largest US companies. Europeans suspect that, relying on their financial power and using the most modern achievements of genetic engineering, the Americans are trying to establish total control over the world market of agricultural products. That is why the Old Continent met with such wariness the demands of the United States to obtain licenses from European countries for the cultivation of its modified crops.

European agrarians fear that the widespread distribution of more sustainable and economic transoceanic GM varieties will lead to a sharp drop in prices for agricultural products and the rapid displacement of "natural crops". As a result, the entire world agricultural market will become completely dependent on American companies. Thus, the issue of the spread of GM crops turns into an acute political problem. "Always in the history of mankind, control over food products has been the most basic and powerful weapon, now the USA is seeking absolute control over it," said one of the participants in a recent discussion on the BBC. Be that as it may, the active offensive of American HMPH on the world market, which began several years ago, already covers more than one thousand names. These products are sold in stores all over the world. In the United States itself, the annual volume of the food biotechnology market is currently estimated at 50 billion dollars. And outside the United States, GM soy and beans can even be found in bread and chocolate.

American advocates of genetic engineering, relying on accumulated experience, prove that the cultivation of new varieties of agricultural crops obtained with the help of biotechnology is completely compatible with the preservation of a healthy environment. In 1999, 28 million hectares of arable land (arable land) around the world were set aside for these crops without apparent loss for it. The products produced at these sites, as reported by the American press, were tested by regulatory authorities for their impact on health and the environment, and were found to be in full compliance with existing safety standards. Where GM seeds have been allowed, "farmers have enthusiastically used them because of the many advantages they offer over traditional varieties."

True, recently the initial enthusiasm of American farmers, on whose fields the fruits of genetic engineering are grown, has begun to fade. Under the influence of the antigenic company, they are quietly reducing the areas devoted to these cultures. According to the statistics of the US Department of

Agriculture, in the spring of 2000, 24% less land was allocated to genetically modified corn. In the eight states that are mainly soybean producers, 52% of all areas were devoted to GM plants – 5% less than a year earlier. GM crops in the five leading cotton-producing states suffered an even greater loss of 7%. The fact that they are not afraid of pests and weeds did not change the situation. Farmers are a pragmatic people: when they discovered that they began to earn less for their modified plants than for traditional crops, American field workers drew appropriate conclusions.

Despite this, the struggle continues. In the age of information explosion, the fate of scientific developments is decided not only in laboratories, but also on the pages of newspapers, on television and radio, using all possible means of mass information (mass media). Understanding this, biotechnological companies spare no means to use the mass media to "stab" into the mass consciousness the belief that food products from genetically modified plants are not only safe for health and the environment, but also have indisputable advantages. For the appropriate treatment of consumers, the Union for Biotechnology Information was created, which included seven whales of the chemical industry, including "DuPont", "Monsanto", "Astrazeneca" and "Novartis".

Probably, it will take a worthy place in the history of the world advertising business. First of all, the union decided to allocate 50 million dollars for the development of a 3-hour PR campaign. Based on the fact that, according to experts, the concern of the American population about biotechnology is still at a rather low level, advertising services intend to gently and decisively, step by step, create a positive image of genetic food. Food of the 21st century, or maybe even the third millennium, American scale.

As the representative of the company "Dow Chemical" stated, three main tasks will have to be solved during the campaign. First, to prove that genetically modified plants will reduce the use of harmful chemicals that are used to destroy pests and weeds. Secondly, explain that they will make it possible to increase food production. And the third, derivative, but propaganda-wise most profitable task: poor countries will eventually be able to feed themselves.

This is the position of the business. And how does the government relate to the passion surrounding the invasion of our lives "Frankenstein's food"? No, they did not distance themselves from the solution of this urgent problem, but – how to express it more precisely? – so far they have not been able to agree on which side to approach her. Back in 1992, at an international conference in Rio de Janeiro, a convention on biological diversity was signed, the participants of which undertook the development of international legislation to ensure biological safety. Since then, 168 states, including

Russia, have joined the convention. But there is still no clarity and agreement on this issue.

At the end of February 2000, ministers of ecology and experts from 137 countries gathered in Cartagena (Colombia). It was assumed that they would agree and sign a protocol on security measures. But at the conference, the disputes between the countries producing and importing agricultural products flared up with new force. The first (USA, Australia, Argentina, Canada, Chile, Uruguay) advocated free access to world markets of GMP. The second (in terms of their number, much more) stubbornly insisted on the need to carefully study possible negative consequences from the use of products and living organisms, in the selection and cultivation of which genetic technologies were used. Not only human health, but also preservation of the planet's biosphere depends on this, they argued. As a result, the conference was limited to a decision to continue consultations. While statesmen and scientists are arguing, ecologists and defenders of consumer interests are striving for complete clarity – which products contain GM components? After all, before consuming food, a person has the right to know whether it contains the genes of a scorpion or a deep-sea shark. It is perhaps no more dangerous than eating oysters or crayfish. But we must have a choice.

7. Genetically modified food – how safe is it?

Depending on where you live, you may have had GMPH for breakfast, lunch or dinner today. For example, potatoes with the "built-in" ability to produce a substance that repels insect pests, or tomatoes suitable for long-term storage. The packaging does not always indicate that the product or ingredients are genetically modified, and you will hardly be able to distinguish them from natural ones by taste.

As you read these lines, transgenic soybeans, corn, canola, and potatoes are growing in Argentina, Brazil, Canada, China, Mexico, and the United States. According to some reports, in 1998, 25% of corn, 38% of soybeans and 45? cotton grown in the US is GM to create plants that are resistant to herbicides or capable of producing pesticides. By the end of 1999, approximately 40 million hectares of land around the world were growing GM crops for commercial purposes, although not all of them were for food[13].

Is genetically modified food safe? Is the application of scientific technologies for the cultivation of GM crops a danger to the environment? There is a heated debate in Europe about the GMP. One opponent of this genetic engineering from England said: "I oppose GM food because I consider it dangerous, undesirable and unnecessary."

How can products be genetically modified? Food biotechnology deals with genetic modification of PCs, which uses modern genetics to improve

[13] Т. Пирог Біохімічні основи мікробного синтезу К.: Ліра. 2019. 349с.

plants, animals and microorganisms that are grown for the food industry. Of course, experimentation with living organisms is as old as agriculture itself. The first cattleman to cross the best bull with the best cow in his herd to improve the breed was already practicing primitive biotechnology. The first baker to put yeast into dough used the enzymes of microorganisms to improve his confections. Such traditional biotechnology was based on the use of natural processes to alter food products.

Modern biotechnologies also use living organisms to modify products. But unlike traditional methods, modern biotechnology makes it possible to produce direct and precisely specified modifications of genetic materials taken from organisms. This makes it possible to transplant the genes of completely dissimilar organisms, to make combinations that are impossible in natural conditions. Breeders can now take the properties of single organisms – such as cold resistance from fish, disease resistance from viruses and pest resistance from bacteria from the soil – and insert them into the genome of any plant[14].

Suppose a farmer does not want the potatoes or apples he grows to turn black when cut or hit. The skill of scientists who can remove the gene responsible for blackening and replace it with a modified segment that blocks this process comes to the rescue. Let's consider a situation where a farmer would like to plant beets earlier than the usual time, in order to increase the yield. This is usually not possible because beets freeze in cold weather. But here, once again, biotechnology comes to the rescue, which can transplant the genes of some species of fish that do not freeze in cold water into a plant. As a result, we get a beet that can withstand temperatures up to $-6.5\ ^{o}C$ – that is, the frost resistance of this plant is doubled.

But the transplant of one gene can transfer only limited properties. To influence more complex mechanisms such as growth or drought tolerance, other approaches are needed. Modern science has not yet learned to skillfully deal with the entire arsenal of genes. Moreover, many of these genes have not yet been discovered at all. Today, there are more than 40 genetically engineered products for public canteens. At first glance, they are very useful, because they combine the sum of useful genes from a lemon, fish, spider, etc... But Europeans are very careful, because they are not sure of the reliability and safety of these genetically created products – will the arachnid not give birth fish genetic changes in our children? A long experiment is needed – the length of a human life[15].

January 28, 2000 – the Japanese allowed the trade in meat from cloned animals, and traders are allowed not to mark or indicate in any other way the origin of this type of meat. This is beneficial, as cows are slaughtered at 10-

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[14] Roger L. Lundblad Biochemistry and Molecular Biology Compendium. 2007. 422p.
[15] Lilia Alberghina Protein Engineering For Industrial Biotechnology. 2003. 374p.

12 months, and cloned animals are ready for slaughter in 3-4 months. This brings a lot of benefits, although the study of cloned food continues, and how it affects human health is still not entirely clear. In addition, the Japanese began to study the health of clones, since the assumption is that their health deteriorates with each generation – similar to photocopies, when the 1st copy is still acceptable, and in each subsequent one the quality deteriorates. Besides, Dolly was aging catastrophically fast. And according to a number of physiological indicators in 2000, her biological age was 9-10 years. On February 14, 2003, Dolly, a sheep cloned in July 1996 and already suffering from a severe lung disease, was given a lethal injection in England at the age of 6 (half of the 12 years measured by the sheep). She is survived by her son, Bonnie, who was born naturally. Scientists will continue to study Dolly's tissues for a long time. Perhaps this is the effect of telomeres – the tail residues of DNA, which lead to a shortening of a person's life span.

8. A new "green revolution"?

Even the limited genetic modification of plants gives proponents of biotechnology grounds for optimism. They say that genetically modified plants will cause a new "green revolution". One biotech industry leader said genetic engineering is a "promising tool to help produce more food" for a global population that is growing by about 230,000 people each year.

The use of GM crops has already helped reduce the cost of food. A gene that produces a natural pesticide has been inserted into some plants used for food. This meant that there would be no need to spray toxic chemicals on hectares of crops. Work is now underway to modify legumes and grains with increased protein content, which will be a good support for poorer parts of the world. Such "super plants" will be able to pass on their new useful genes and properties to the next generations, giving abundant (busy) harvests on unprofitable lands in poor, overpopulated countries[16] [17].

"Undoubtedly, farming around the world needs to be improved," said the president of one of the leading biotech firms. we will create improved products that will meet special needs, we will do it faster than before." But, according to specialists in the field of agriculture, the hasty effort to put forward genetic engineering as a solution to the global problem of food shortages has a negative effect on the conduct of modern plant research. Although these studies are not exotic in any way, they bring equally important results that could also contribute to solving problems in poor countries. "We should not chase an unproven technology when there are many other effective ways to solve the food problem," says Hans Herren, a plant disease specialist.

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[16] Трохимчук І. М., Плюта Н. В., Логвиненко В. П., Сачук Р. М. Біотехнологія з основами екології. Навчальний посібник: Кондор. 2019. 539с.

[17] Kimball Nill Glossary of Biotechnology Terms. 2010. 308p.

Studies show that the environmental risk in the case of growing transgenic plants can be compared to the risk of testing new breeding varieties. All compounds found in transgenic plants already exist in nature. However, the speed of manifestation of these signs is different and what happens in nature for thousands and tens of thousands of years is accelerated to years by the methods of biotechnology.

Is there a danger of altering transgenic plants in such a way that they become toxic to humans and animals? Even theoretically, it is difficult to imagine that the introduction of one of the genes into a higher eukaryotic organism, the genome of which consists of tens of thousands of genes, will change its metabolism so much that the plant will begin to synthesize such toxic compounds that are not related to the expression of the introduced gene. Of course, in each case of introducing a new gene into plants, the resulting genetically modified plants must undergo thorough research. At the same time, the metabolic products coded by the introduced genes are studied, and only after that the transgenic plants are studied in the field.

CONCLUSIONS

Some think that, in addition to the threat to human health and the environment, genetic modification of plants and other living organisms creates moral and ethical problems. Scientist Douglas Parr believes: "Genetic engineering goes beyond the accepted human use of the planet's resources, invading the very essence of life. Jeremy Rifkin, author of the book "The Biotech Century" ("The Biothech Century") expresses this opinion as follows: "Once it is possible to overcome biological barriers, biological species begin to be perceived simply as genetic information that can be manipulated. This will lead to the creation of a completely new concept, which concerns not only our relationship with nature, but also how we use it." Therefore, the author posed the question: "Does life have its own value or should it be evaluated only from the point of view of practical benefit ? What debt do we have in relation to the new generations? What responsibility do we bear to the creatures living next to us? "

Others, including the English Prince Charles, claim that by transplanting the genes of completely different biological species, "we are invading the sphere that belongs to God and God alone." Those who study the Bible are convinced that God is the "source of life" (Psalm 35:10). But it cannot be said with certainty that God opposes the selective breeding of animals and plants that helps our planet support the lives of billions of people. Only time will tell if modern biotechnology harms people and the environment. If biotechnology really interferes in the "sphere that belongs to God", then he, with love and concern for humanity, can turn this process back.

Hunger is a derivative of corporate interests, for the last 60 years biotech companies and some scientists have argued that humanity needs genetically modified plant species to feed itself and protect the planet from chemicals. In fact, there is enough food for everyone. Famine, paradoxically, is the result of economic benefits, new technologies and structures that "exploit the deficit".

For centuries, ruminants have turned grasses and other "inedible plants" into high-quality proteins for humans. These were a kind of four-legged factories for the production of protein. But one day we learned how to graze cattle on arable land. Only a small part of the fed nutrients returns to us together with the meat, the rest is "not so productively" consumed by the animals themselves. 30 years ago, one third of the world's grain reserves were fed to cattle, today it is almost half. Today, humanity is doing the same "trick" with fish. By feeding fish with fish, we reduce efficiency and do not think about the problem as a whole. Hundreds of millions of starving people cannot grow enough fruit, so they eat meat. The grain turns into a small fillet. Sardines in salmon. The situation itself offers a wide field of activity for biotechnologists.

Increasingly, public discussions on the problem of starvation take place against the background of advertising by international corporations that control both the production and distribution of products, as well as the seed fund, which can influence the development of the industry. Famine is not a consequence of a lack of products, but of a lack of democracies. This is why this problem will never be solved by new technologies, even if we are convinced that they are safe. The problem will be solved only when the citizens create democratic institutions and the government will reckon with them, and not with private corporate interests.

Summary

In modern biotechnology, biological systems of all levels are used – from molecular genetic to biogeocenotic (biosphere). At the same time, fundamentally new biological systems are created that are not found in nature. Biological systems used in biotechnology, together with non-biological components (technological equipment, materials, energy supply, control and management systems) are usually called working systems.

Biotechnology expands research in the field of development and production of: microbiological means of plant protection against diseases and pests; bacterial fertilizers and plant growth regulators, increasing soil fertility; new varieties and hybrids of agricultural plants with specified properties, highly productive and resistant to adverse environmental factors, obtained by methods of genetic and cellular engineering; valuable feed additives and biologically active substances (forage protein, amino acids, enzymes, vitamins, veterinary drugs, etc.), necessary for increasing the productivity of animal husbandry; new methods of bioengineering for effective prevention, diagnosis and therapy of the main diseases of farm animals; new technologies for obtaining economically valuable products for use in the food, chemical, microbiological and other industries; technologies of deep and effective processing of agricultural, industrial and household waste; use of wastewater and gas-air emissions to obtain biogas and high-quality fertilizers; production of cheap and efficient energy carriers (biofuel); new biologically active substances and medicines for medicine (interferons, insulin, human growth hormone, monoclonal antibodies, etc.), which increase the quality of human life and allow early diagnosis and treatment of serious diseases – cardiovascular, oncological, hereditary, infectious, including viral ones.

Currently, microorganisms are used in various high technologies: for the production of antibiotics, feed protein and amino acids, biologically active compounds (vitamins, hormones, enzymes, growth stimulants), etc. The transformation of one substance into another with the help of microorganisms is called bioconversion. In microbiological synthesis, prokaryotes (bacteria, actinomycetes) and fungi are used as microorganisms, and various sources of carbon (natural hydrocarbons, organic waste), mineral salts and atmospheric nitrogen serve as raw materials.

Applying the methods of genetic and cellular engineering, modern biotechnology carries out extensive construction of genetically modified organisms (GMOs), including microorganisms, plants and animals. In the future, GMOs are expected to be used in natural conditions (in agriculture, fish farming, for biological control of agricultural and forestry pests, etc.). However, genetic engineering poses a number of ethical and technological problems related to their impact on living organisms. When GMOs enter the environment, they can interact with various organisms, communities and ecosystems of specific territories, while the processes and results of such interactions are not always predictable. In particular, there is a danger of introducing "artificial genes" into the genome of natural organisms as a result of crossing GMOs and "wild" forms. Because of the possible unintended consequences, it is necessary to conduct research aimed at studying the biosafety of GMOs.

Bibliography

1. Biotechnology and Natural Products: Prospects for Commercial Production Albert Sasson. 1992. 112 p.
2. Feeding Tomorrow's World Albert Sasson, Unesco. 1990. 814p.
3. Бабенюк Ю.Д., Антипчук А. Ф. Мікробілогія Киïв. Університет «Украïна» 2010. 150с.

4. David R. Wessner, Christine Dupont, Trevor C. Charles, Josh D. Neufeld Microbiology. New York. Wiley. 2022. 1024 p.

5. Пирог Т. П. Загальна мікробіологія: підручник / Т. П. Пирог. К. : НУХТ, 2004. 471 с.

6. Пирог Т.П. Загальна біотехнологія: підручник / Т. П. Пирог, О. А. Ігнатова. К. : НУХТ, 2009. 336 с.

7. Ніколайчук В. І. Генетична інженерія: підручник / В. І. Ніколайчук, І. Ю. Горбатенко. Ужгород. 1999. 182 с.

8. Біотехнологія: Підручник / В.Г. Герасименко, М.О. Герасименко, М.І. Цвіліховський та ін.; Під ред. В.Г. Герасименка. К.: ІНКОС, 2006. 647 с.

9. Юлевич О. І. Біотехнологія : навчальний посібник / О. І. Юлевич, С. І. Ковтун, М. І. Гиль ; за ред. М. І. Гиль. Миколаїв : МДАУ, 2012. 476 с.

10. Biotechnologies: Challenges and Promises Albert Sasson, Unesco. 1984. 328 p.

11. Biotechnologies and Development Albert Sasson, Unesco. 1988. 361 p.

12. Яблонський В. А. Біотехнологія відтворення тварин: підруч. / В. А. Яблонський. К. : Арістей, 2005. 296 с.

13. Т. Пирог Біохімічні основи мікробного синтезу К.: Ліра. 2019. 349с.

14. Roger L. Lundblad Biochemistry and Molecular Biology Compendium. 2007. 422p.

15. Lilia Alberghina Protein Engineering For Industrial Biotechnology. 2003. 374p.

16. Трохимчук І. М., Плюта Н. В., Логвиненко В. П., Сачук Р. М. Біотехнологія з основами екології. Навчальний посібник: Кондор. 2019. 539с.

17. Kimball Nill Glossary of Biotechnology Terms. 2010. 308p.

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