

Rainbow code of biotechnology

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Introduction

Biotechnology is considered as one of the disciplines, development of which will decide about proper evolution of economy in XXI century. It is a broad area of technical activity and its development is dependent on cooperation between various disciplines of science. Paradoxically, being a new branch of science, biotechnology is simultaneously one of the oldest branches of economic activity.

Term “biotechnology” derives from three Greek words: *bios* (βίος) - life; *technos* (τεχνήσις) – technology and *logos* (λόγος) - thinking.

There exist a vast variety of definitions of biotechnology. Presumably the most general one is given by The United Nations Convention on Biological Diversity, which states that it is „*any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use.*” Perhaps the simplest one is provided by *Wikipedia*, which defines biotechnology as a field of applied biology that involves the use of living organisms and bioprocesses in engineering, technology, medicine and other fields requiring bioproducts [1]. Finally, also the definition of Polish Ministry of Science and Higher Education, adapted after OECD (Organization for Economic Co-operation and Development) should be given here. It says that „*Biotechnology is interdisciplinary branch of science and technology dealing with transformation of living and inanimate matter by the use of living organisms, their parts or products derived from them, as well as creation of models of biological processes in order to produce knowledge, goods and services*”.

Rainbow code of biotechnology

Although there several classifications of biotechnology, the one using color code is most popularly used. Most commonly four major colors are considered, namely red, green, white and purple. However classifications using many more colors, nearly all tones of rainbow, also exist.

As any classification also this one is not precise and synonymus. Some of the colors describe very wide and well developed ranges of biotechnological activities, while other ones are dedicated to branches being in their infant forms. Quite obviously various authors present different classifications, which not necessarily are the same. For example, many literature sources under the name “white biotechnology” code both industrial processes and environmental engineering, whereas some others divide these two branches under white and gray code. Different division of industrial and environmental biotechnologies is also based on the use of genetically modified organisms (white biotechnology) and traditional fermentations (gray one). As seen from these examples color code of biotechnology is being formed now and should not be treated as orthodox.

The biggest number of colors is used by the code, which divides biotechnologies into (*Electronic Journal of Biotechnology*):

- green one, which is devoted to the development of agriculture
- yellow one, which might be called nutritional biotechnology
- red one, which is devoted to medicine and human health
- white one, namely industrial biotechnology
- gray one, which is devoted to the problems of environmental protection

- blue biotechnology of marine (aquatic) regions
- brown biotechnology of desert and dry regions
- gold one, which is connected with bioinformatics, computer science and chip technology
- violet one, which deals with law, ethical and philosophic issues
- dark biotechnology connected with bioterrorism and biological weapons.

This classification is also incomplete, since it does not consider, for example, nanotechnology, which is being developed vigorously recently. Luckily enough there are still some rainbow colors left unused.

Green biotechnology

A far as in XVIII century reverend Thomas Malthus analyzed the relations between population growth and availability of food [2]. These studies have pointed out that humanity will face permanent shortage of food resulting from that the growth of population significantly overgrowths potential of agriculture for producing food. That this concept has not to be necessarily true is shown during last two hundreds years when the production of food thanks to development of science (especially “green revolution”) was sufficient or sometimes even bigger than the needs.

Green biotechnology is commonly considered as the next phase of green revolution and brings hope to defend hunger on Earth. It uses technologies, which enable to produce more fertile and resistant, towards biotic and abiotic stress, plants and ensures application of environmentally friendly fertilizers and the use of biopesticides [3]. Major technologies applied here are:

- plant cells and tissue cultivation and micropropagation
- application of molecular engineering for selection of plants (and to the lower extent animals) with designed properties (GMO)
- marker assisted selection - the use of tools such as molecular markers or DNA fingerprinting can map thousands of genes. This allows plant breeders to screen large populations of plants for those that possess the trait of interest
- reverse breeding and doubled haploids - a method for efficiently producing homozygous plants from a heterozygous starting plant, which has all desirable traits.

The application of these technologies awakes emotions and controversies [4, 5]. Unnecessary if considering that down of history genetic modifications were the basis of breeding of plants and animals. Moreover, there is no example of domestic plant or animal, which would not be genetically modified. Doubts and fears about this matter are results of lack of knowledge about relations of these new technologies with traditionally applied selection ones.

So called “golden rice” is a good example here. It contains genes of daffodil encoding production of β -carotene, a precursor of vitamin A [6]. Traditional Asian food severely lacks in this vitamin. Despite the fact that over 230 millions of people suffers night blindness and the number of Asian children, who have to use glasses, is alarming golden rice has not been introduced because of the action of ecological organizations. Greenpeace has even named this rice “Pandora’s box” [7].

Red biotechnology

Biotechnology in health preservation, medical or pharmaceutical biotechnology are synonyms of red biotechnology. It considers production of vaccines and antibiotics, discovery of new drugs, regenerative therapies, construction of artificial organs and new diagnostics [8]. All of these subjects are not controversial despite that they use techniques of molecular biology. For example tomatoes protecting against cancers by increased level of anthocyanins [9], or lettuce being a vehicle of anti-hepatitis vaccine [10] attached considerable interest and goodwill. Transgenic animals-derived drugs against life-threatening diseases, such as: antithrombin III (against genetic resistance to heparin; produced by recombinant goats and Chinese hamsters), recombinant blood factors (for curing haemophilia; sheep) and α 1-antitrypsin (to cure emphysema and pulmonary fibrosis; sheep and goats) [11 ÷ 15] are also fully accepted. *Gensulin*, produced by Bioton, is also a good example here. It is a recombinant human insulin produced by microorganisms [16]. This drug enabled to save significantly Polish spending on this drug by lowering its price and decreasing its import. Far more controversies arouse around genetic therapies because they resulted in controversial results so far, making that it is still experimental-type of medication [17].

There is a general agreement that diagnosis will be the basis for further development of medicine. Huge potential of diagnostic methods is based on the development of molecular diagnostics, various “-omics” (genomic, proteomic, metabolomic and related ones), the application of arrays of antibodies or arrays composed of enzyme substrates and inhibitors and on miniaturization of diagnostic devices (such as lab-in-chip systems) [18].

Companies dealing with red biotechnology comprise 50% of Polish biotechnological companies and their number is still growing. Today, many valuable products obtained by applying methods of molecular engineering are available, to mention only: hormones, stem cells, monoclonal antibodies, siRNA and diagnostic tests.

White biotechnology

White biotechnology or industrial biotechnology relays on application of biocatalysis in industrial processes. Such processes develop dynamically and concur with classical technologies [19]. They are worldwide used in: chemical, pharmaceutical, cosmetic, paper, textile, tanning and food industries, as well as in power industry. White biotechnology is considered as the biggest branch of biotechnology and deals with:

- replacement of traditional industrial processes by biocatalytic ones in order to obtain valuable products, such as: pharmaceuticals, cosmetics, fine chemicals and food additives
- production of biodegradable polymers as well as those of specific properties (including “smart polymers”)
- production of fuel starting from renewable resources or by the use of photosynthesizing microorganisms (including genetically modified ones)
- production of industrially relevant enzymes and microorganisms.

Special emphasis is put on the use of renewable substrates and environmentally friendly processes, what makes that white biotechnology is considered as a component of “green chemistry” [20].

Building up biorefineries is a new trend of white biotechnology [21]. This concept derives directly from functioning in traditional petroleum refineries: the raw material is fractionated in order to obtain a series of valuable products. Diversity of biomass composition ensures both production of raw chemicals (such as biofuels) and valuable fine chemicals (such as pharmaceuticals), accompanied by generation of heat and energy required for proper functioning of the plant.

Violet biotechnology

As any new field of human activity, which is entering extensively and dynamically human life, biotechnology is causing doubts and fears, as well as law problems mostly connected with patenting of its inventions. Thus, quite serious moral dilemmas and ethical discussions have emerged. This matter is a sphere of activity of ethicists, philosophers and churches - thus convictions of people will differ significantly. This results in astonishing atmosphere of dispute between followers and adversaries of biotechnology.

Appearance of these problems caused the formation of new discipline of biotechnology, called violet biotechnology, devoted to regulation and resolving of these problems and formation of a platform for discussion [22]. The violet biotechnology started from June 16th, 1980 when the US Supreme Court came to a decision that genetically modified microorganism can be patented.

Remaining colors of biotechnology

The described four branches of biotechnology are considered as major ones (assuming that environmental biotechnology is a component of white biotechnology). In this paragraph three examples of the remaining branches will be discussed, yellow, blue and brown.

Yellow biotechnology is, perhaps the oldest branch of biotechnology because it considers production of human and animal food (however, according to another classification yellow biotechnology refers to biotechnology with insects). Nearly 10,000 years ago, our ancestors were producing wine, beer, cheese and bread by using fermentation. For example, Egyptians applied fermentation technologies to make dough rise during bread making. Due in part to this application, there were more than 50 varieties of bread in Egypt more than 4,000 years ago.

Today, the main goal of yellow biotechnology is improvement of certain food to obtain the most nourishing one and fortified with health-promoting additives. It is reached by enzymatic and microbial (also applying genetically modified ones) processing of food, elimination of allergens and components causing its intolerance or its fortification with health-promoting components. So called functional food is of special interest of yellow biotechnology [23]. It is also called health-promoting or nutraceutical one. Idea of functional food derives from philosophic tradition of Orient, since there is no strict difference between food and drug. It is commonly approved that one of the means disease prevention is appropriate and well-balanced diet. Hypoallergenic rice discovered in Japan in nineties of the preceding century is considered as precursor of functional food [24]. There are currently three directions of food processing to obtain functional food influencing gastrointestinal tract, circulatory system and immune system.

Blue biotechnology is based on the exploitation of ocean and sea resources to create products and applications of industrial interest. Taking into account that the sea presents the greatest biodiversity, there is potentially a huge range of sectors to benefit from the use of this kind of biotechnology. No doubt specific raw materials from the sea represent the most widespread blue biotechnology in many different sectors. These materials, mostly hydrocolloids and gellings are already being widely used in food, health treatment and cosmetics. Next-generation of biofuel produced by photosynthetic microalgae is the newest marine-derived raw material. Most probably these bio-oils could be used to manufacture a full range of fuels including gasoline, diesel fuel and jet fuel that meet the same specifications as today's products. Medicine and research are other major beneficiaries of development in blue biotechnology. Some marker molecules from marine organisms are now commonly used in research. Enzymatically active molecules useful in medicine, diagnostics and research have also been isolated from marine organisms.

Brown biotechnology considers management of arid lands and deserts [27]. They make up a large part of Africa, where two-thirds of the continent is desert or drylands. Half the continent's population

is found in these areas. Also, some of the poorest countries in the world, with heavy population growth, meager national resources, a weak or negligible technological base, primary level education, and inadequate technical infrastructures are here. Against this background, the use of GMO technology could make a beneficial impact through the use of improved seeds and disease-free high-quality plants to grow high-value commercial crops in low-rainfall areas. Especially cultivation of desert crops, development of saline agriculture and aquaculture, and the rational use of water, wastewater and other water resources is of special interest.

A good example of possibilities offered by brown biotechnology is one of the most fascinating projects, which was developed recently by Magnus Larson, a Swedish architecture student, which can be put into practice [28]. His thesis is based on the need to stop the spread of the Sahara desert using *Bacillus pasteurii* bacteria which excretes gluing substances and calcium carbonate and are able to set the dunes just like concrete after twenty four hours. These bacteria are capable of constricting a wall of 6,000 kilometers long between Djibouti and Mauritania. Larson suggested that it is possible to form a wall from the existing sand dunes in the region through covering the dunes with *Bacillus pasteurii* commonly found in wetlands regions. The bacteria are non-pathogenic and die in the process of solidifying the sand. This part of the project relies upon research carried out by professor Jason De Jong at University of California at Davis, as well as conversations with biochemist - professor Stefano Ciurli at the University of Bologna [29].

Summary

Biotechnology is considered as a driving force of progress and simultaneously as a major threat of humanity. This impetuous controversy considers mainly green biotechnology. White and red biotechnologies are far less contentious because they provide perceptible, positive results from consumer or patient point of view; often they save human health or life. It is, however, worth to note that cultivation of GMO plants, although give rise of anxiety, are bringing visible benefits. For example, introduction of resistance of sweet potato against one viral disease might bring in Africa 60% increase of its crop, practically immediately without any additional cost. This raises the question if satiated, white ecologist has a moral right to undertake action against introduction of this GMO plant in Africa.

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Translation into English by the Author

Paweł KAFARSKI, professor of Wrocław University of Technology and University of Opole. He occupied and occupies many academic functions out of which especially important was presidency of Polish Chemical Society. Co-authored over 300 papers, which are cited over 3,000 times in the scientific literature. His scientific interests consider design, synthesis and evaluation inhibitors of certain enzymes for potential application in agriculture and medicine, application of biocatalysis in organic synthesis and synthesis and evaluation of biologic and chemical properties of aminophosphonates and their derivatives. Amongst prizes and honors he highly appreciates Jana Hanus medal given by Czech Chemical Society and Włodzimierz Trzebiatowski medal awarded by the Senate of Wrocław University of Technology. He is especially grateful to, dr Zbigniew Czarnuch (historian at high school) and prof. Przemysław Mastalerz (academic teacher), tutors who formed his personality.

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