Basic and Applied Biotechnology: A Response to the 21st-Century Challenge

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In the first place, let me make it clear that biotechnology is not a response to the challenge of the 21st century. Paradoxically, the present-day achievements of biological sciences and biotechnology are a unique challenge predetermined by the unprecedented possibility to develop new genetic programs. Human-kind will have to address this challenge.

Only recently and even today, the construction of bridges, aircraft, ships, and factories has been an act of creation, clear and important for each and every person. Over the past few decades, scientists have understood that they can master processes that required the efforts of the Creator and millions of years of evolution. Today, people can create and adjust genetic programs written by nature. The new possibilities of basic research and genetic engineering have astounded modern society, and now it has to conceive anew the old concepts of the formation and function of living organisms and their genetic basics.

At the beginning of the current century, biotechnology, based on gene engineering methods, became a key component of the world economy. The formula “The economy of the 21st century is a knowledge-based bio-economy” has not emerged by chance.

Upon transforming into multicolored varieties (according to the modern classification), biotechnology penetrated in all spheres of modern life. Depending on the field of application, it is called “red” (medical), “green” (agricultural), “white” (industrial), “blue” (marine), or “gray” (environmental).

The demand for red biotechnology is most obvious: over the past two decades, it has made a valuable contribution to the production of new generation of effective medical preparations, from antineoplastic to antidiabetic.

The huge funds spent all over the world on biotechnology are undoubtedly justified. However, we have to state that biotechnology in Russia is developing more slowly than abroad. One of the possible factors behind this lag is no doubt the traditional Russian indifference to human health.

In turn, agricultural (green) biotechnologies, which are designed to solve food and environmental problems, are, in fact, also targeted at improving the quality of human health.

In the chemical and microbiological industries, biotechnologies are successfully involved in the production of medicines and biologically active substances. Blue biotechnologies are topical for the development and support of maricultures that optimally use and restore marine resources.

The wide range of applications of biotechnology in the economic sphere is a favorable background for revolutionary discoveries in biology made over the past 10–15 years and awarded with about 20 Nobel Prizes.

Gene engineering, the polymerase chain reaction method, and the possibility to construct high-velocity sequenators and microchips are technologies that predetermined the main achievements of world science: the breakthrough in genomics and the mapping of the human genome, which is unprecedented as far as its social potential is concerned, and the rise of new sciences, such as proteomics, metabolomics, and transcriptomics, as well as a new promising approach to the study of living matter using data of system biology and bioinformatics.

Deep knowledge about Homo sapiens and the genetics of living organisms, which was accumulated exceptionally quickly at the turn of this century, poses difficult tasks before humankind. We are again facing the choice between narrow-mindedness and inertia, on the one hand, and the active perception and application of new knowledge, on the other.

The first challenge to humankind, resulting from the development of genomics, is the necessity to learn how to read and analyze genetic texts. If we do not learn how to read, we will repeat the fate of R. Kipling’s tongueless hero. Those who can read genetic information will never become tongueless Mowglis.

The second challenge is like learning how to write, when pupils begin compiling words and phrases from letters and reproducing them on paper. In the language of genetics, this means a transfer to manipulating known genes and creating new, previously unknown in nature, genetic texts. A technological breakthrough like this makes society feel concerned and anxious.
Finally, let us advert to the third challenge. Just like in everyday life, when, upon mastering the skills of reading and writing, an individual enters the system of education, humankind must transfer to the creation of a system that could make it possible to enter genetic information into organisms and to create new organisms. The decisive answer to the challenge of science and time depends on how humanity will manage and use the results of this introduction. An optimistic forecast implies the development of gene therapy, the creation of tissues and organs with required architectonics, and blossoming of the transplantation of organs and tissues in the near future.

To illustrate all these processes, we may use simple examples. Figuratively speaking, genetic information contained in the genomes of omnipresent microorganisms (in each of them) consists of about 2.5 million letters. Their number equals the number of letters on the pages of L.N. Tolstoy’s War and Peace. To compare the text of War and Peace and the genetic text contained in one microorganism is a strikingly accurate analogy.

The human genome consists of six billion letters, three billion from each parent. This is practically Tolstoy’s complete library in Yasnaya Polyana. It is difficult even to flip through all the books in this library. To read the human genome, it was necessary to solve a complex of informational, biological, technological, and other problems.

Scientists were purposefully involved in studying in detail the human genome for ten years.

The example of this project that united practically the whole world shows that the rates of this work were consistently increasing. At present, the genomes of six people have been mapped. The mapping of the first genome (in 2001) took the entire previous decade and $3 billion, while the mapping of a human genome in 2007 took only one year and cost $200 million. Today, the mapping of an individual genome takes 100 days and costs $2 million. In the future, the cost will drop to $1000 and the mapping will take one day. The relinquishing of bulky and heavy old equipment makes it possible to fundamentally change the approach to the reading of genetic information. Reading individual molecules is nothing but nanotechnology. By 2010–2012, it will be as easy as taking a blood test.

Each of us has individual genetic information. Genomes of different people are not identical. For example, the genetic information of the Chinese and Africans contains ethnically determined differences in several letters, several phrases, or several sentences. To date, genetic maps of populations by ethnicity have already been developed.

If we replace one letter in War and Peace, getting, for example, Wag and Peace, this will change the meaning altogether. To put it bluntly, sometimes, the substitution of one letter in the genome can make a healthy individual sick and genetically “different.”

Today, we are working with a miniature chip on which up to 40 million dots are localized, allowing us to carry out genetic tests. Through a blood test, the chip helps determine whether there are errors in the patient’s genetic material and whether this patient is prone to any diseases.

We have begun pioneering studies of the populations living east of the Urals. This is the only remaining “blank spot” on the genetic and ethnical map of the world. Along with Western scientists, the Chinese and Indians are actively working in this sphere; they have made such maps with regard to the population of China and India.

Until recently, there was no such ethnic–genetic information about Russia. We conducted comparative genetic analysis of a group of Ural Old Believers and the Russians, Kazakhs, Buryats, Chinese, and Yakuts who are still living on Russian territory. The findings made it possible for the first time to construct multidimensional genetic maps of Siberian territory and to discover a strict correlation between the geographical coordinates of the habitats of Siberian peoples and the structure of their genetic information.

The Russian Ministry of Health and Social Development, which is interested in identifying human populations prone to specific diseases, also needs genetic and ethnic maps.

Without constructing genetic maps and thus filling in the blank spots on Russian territory, we will be unable to keep pace with world science and to become involved in the development of the world genetic map.

Recently, we in cooperation with linguists began to compare genetic distances with language distribution. We have discovered that the evolution of languages and the evolution of genetic characteristics fully coincide. Promising cooperation may also be an attempt on the reverse drift toward protolanguage and the “protohuman.”

Now let us turn to diseases. A topical problem today is to forecast proneness to a disease and the possibility to control it. I would like to give only one graphic example, AIDS. If a receptor in human cells is changed, HIV loses its ability to bind with them, and a potential patient cannot be infected. Note that many inhabitants of Iceland are resistant to AIDS, while all Asians are prone to it. The Institute of Immunology of the Russian Ministry of Health and Social Development deals with such issues. It turned out that Pomors are close to Scandinavians in this respect. The distribution of the genetic characteristics of different nationalities—Yakuts, Russians, Kazakhs, and others—fully corresponds to the geographical picture. Blood test results make it possible to localize the position of a nationality (as a whole) on the geographical map.

Today, it is already possible to discover the proneness of an individual to different diseases, such as diabetes and certain types of cancer. Recommendations would be premature today, but we do have respective