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ETHICAL ASPECTS OF MODERN BIOMEDICAL TECHNOLOGIES: IS THE CONVERGENCE OF SCIENCES A BENEFIT FOR PRESERVING HUMANITY AS A SPECIES?

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Abstract. Modern advances in biotechnology, genetic engineering, and nanotechnology offer unprecedented opportunities to improve human health and longevity. However, these innovations also introduce complex ethical challenges. This article explores the role of bioethics in distinguishing the moral boundaries of interventions in living organisms, emphasizing the distinction between therapeutic applications and human enhancement "for the sake of improvement".

In this article we highlight the convergence of NBIC technologies (nano-, bio-, info-, and cognitive sciences) as a transformative force for healthcare and improving quality of life. Illustrate how natural models inspire technological solutions using avian wing designs and hydrophobic surfaces as examples of bioinspiration and biomimicry. Additionally, this article discusses the application of biomimetic nanomaterials in implantology and targeted drug delivery, while emphasizing the potential of natural bioactive compounds as alternatives to synthetic agents.

Special focus is given to catalytic antibodies (abzymes) for treating addictions and cancer, and the use of transgenic plants in vaccine production. Emerging molecular technologies such as molecular imprinting and omics-based systems, particularly metabolomics, were examined as promising tools for more precise physiological monitoring. Genetic polymorphisms were analyzed in relation to toxic substance metabolism and disease susceptibility.

Furthermore, we discussed the study of the genome of the "immortal jellyfish", which offers new insights into cellular rejuvenation. We reviewed genome editing tools like CRISPR-Cas9 as such that hold revolutionary potential, for example, for cardiac tissue regeneration. However, they also pose risks of uncontrolled genomic alterations, especially in germline cells. This raises critical ethical concerns regarding the right to life, privacy, and equitable access to advanced medical technologies.

However, advances in biotechnology and nanotechnology offer important solutions to a number of human health issues. In particular, the use of nanomaterials, biotechnology, genetic engineering, complex mechanical systems and nanorobots has improved the accuracy of diagnosis, bioavailability of drugs and treatment options in oncology, regenerative medicine and dentistry for a number of genetic diseases. At the same time, the use of modern biotechnologies may carry potential risks of uncontrolled changes to the genome, especially when interfering with reproductive cells. The combination of nanotechnology with genetic engineering, artificial intelligence-based diagnostics, and biosensors raises questions about confidentiality, transparency of safety assessments, and clinical trials. This has sparked debate among a wide range of scientists about the right to life, confidentiality, and access to the latest methods.

In conclusion, the rapid development of biotechnologies, particularly at the nanoscale, presents vast potential for diagnosing and treating genetic diseases, cancers, and addictions. Nonetheless, these advances require rigorous ethical oversight to safeguard human dignity and prevent unintended consequences.

Keywords: bioethics, convergence of sciences, genetic engineering, imprinting, biotechnology, transcriptomics, metabolomics, omics technologies.

Introduction. Humanity's drive to improve quality of life and extend longevity is the driving force behind the development of science and technology, particularly modern biotechnologies. Therefore, the physical component of a person's quality of life is based on the idea of an individual's biological safety and is closely linked to healthy food, clean water, and an adequate environment. Modern achievements in the fields of biotechnology, genetic engineering, cloning, and nanotechnologies necessitate a new societal definition of attitudes towards humans as both a natural and socio-cultural value. This raises issues concerning moral regulations and "standards" that permit or prohibit certain biological interventions in the human body.

Bioethics must define what is moral or immoral regarding living beings and life in general. This means that certain scientific research and medical actions involving the use of novel biotechnologies in the form of gene therapy, cloning, artificial insemination, and transplantation fall within the scope of bioethics. However, genetic engineering can be used not only for therapeutic purposes, but also for the purpose of changing human biology, essentially constructing the body according to desire [1]. So-called "improvement for the improvement's sake". Obviously, in the sense of morality, there is a fundamental difference between intervention at the genetic level to alter something that is malfunctioning and intervention to create a more "perfect" biological being. It is in this regard that

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bioethics attempts to address the question of whether such intervention in human biology is moral. From a bioethical perspective, new aspects also arise for evaluating such medical procedures as abortion or euthanasia.

Recognizing the biological value of humans as individuals, the global community, in its pursuit of humanizing scientific research, must strive to improve the ethical and legal standards of biomedical and genetic research. The importance of such standards will demonstrate society's acceptance of new challenges, and its awareness of the significance, essence, and content of the role of bioethics in preserving humans as individuals and humanity as a whole.

When studying the interconnections and interrelations in the chain of Human – Society – Culture – Technology (the so-called NBIC convergences), it is difficult to avoid the pitfalls of various positively or negatively colored views on the social consequences of the use of technology, especially novel technologies. In the future, the global societal evolution and scientific development will lead to the fusion of technology and human intelligence. The current stage of "convergent technologies" refers to combinations of biotechnology, biomedical technologies (including genetic engineering); information technology (including advanced computing equipment and communications) and cognitive science, including neuroscience. In light of this, the medical sciences are an integral part of these convergences, as they interact to varying degrees with all their components and are aimed at improving quality of life and increasing work capacity. The development of biomedical technologies has enriched science with new technologies and terms, such as bioinspiration, biomimicry, omics technologies, sequencing, metabolomics, and others [1-3].

The aim of the study. The purpose of this study is to analyze the current state of implementation of biomedical, nano and gene technologies aimed at prolonging human life and health, and to assess the moral, ethical and legal approaches to defining the limits of what is permissible in the application of these achievements.

Materials and methods. Analysis of specialized and scientific-methodological literature.

Object and methods of research. The ultimate outcome of scientists' efforts in the field of bioinspiration and biomimicry is the modern aircraft. The wingtip of an airplane is biomimetic, and its fundamental function of minimizing turbulence is an improvement on nature's original – the bird's wing. Whereas nano-3D printing is an example of a new method of bioinspiration. Plants and animals possess special properties, often related to the composition of their nano- and micro-surface structures. Some plant parts have water-repellent properties, for example, such as the petal of *Nelumbo nucifera* (lotus), which is self-cleaning due to the presence of a hydrophobic coating. Many researchers have already attempted to mimic the leaves of *Salvinia Molesta* which are superhydrophobic due to the presence of various types of water-repellent (superhydrophobic) hairs [5-7].

Other examples of bioinspiration are the study of the toes of geckos, which work by increasing the value of Van der Waals force, leading to adhesion even on slippery surfaces, or that of butterfly antennae, which inspire scientists to find new approaches for detecting chemical leaks, drugs and explosives. Currently, there are many technical applications based on bioinspiration. Recently, multifunctional polymers (biomimetic materials) have appeared, possessing biocompatible, biodegradable, or other functional properties of natural objects [5].

Biomimetic materials allow engineers to develop devices that have significant practical importance for nanoelectronics, wireless communications, nanotubes, and biomedical devices. The oleophobic effect, which a biomimetic material based on the lotus effect can easily provide, is useful for cleaning adhered fuel residues from the surfaces of pipes, fuel tanks, etc. Bioactive natural compounds, by definition, are a source of new products that can be alternatives to synthetic molecules or solutions to fundamental or technological problems.

A polycarbonate substrate with selenium nanoparticles can be used to prevent the formation of microbial biofilms, which cause the development of resistant microorganisms. Polyol, created on the basis of glycerol and combined with silicon dioxide, is used as a potential carrier for drugs, such as, doxorubicin hydrochloride [8]. The formation of silicon nanoparticles based on biofilms that form on the surface of suspensions is at the heart of the development of new devices and coatings. Physiologically active substances of plants (including enzymes, vitamins, phytohormones, antibiotics, phytoncides, inhibitors) are also biomimetic materials.

Biomimetic nanomaterials in implantology are an extremely important area of research for the rapid recovery of patients with bone fractures, increasing the shelf life of implants, or for the safe resorption of implants with subsequent excretion, in connection with physiological requirements, from the body [3]. Implants used in orthopedic surgery contain osteoprogenitor cells and osteoinductive growth factors. The development of highly biocompatible, elastic and durable biomimetic nanomaterials is for improving regenerative medicine in orthopedics and traumatology. Improving the integration of biomimetic nanomaterials into the human body is the basis for further scientific developments in the fields of biology, chemistry, and medicine in order to use them for the prevention, diagnosis and treatment of various diseases [1-4].

Already by their definition, bioactive natural compounds are a source of new products that can be alternatives to synthetic molecules or answers to fundamental or technological problems. Advances in the study of the interaction of natural compounds with the extracellular matrix, cell receptors or plasma membranes, as well as their modulating effects, have made it possible to optimize the bioavailability of these biomolecules for their final valorization in food or pharmaceutical products.

Currently, malignant neoplasms are one of mankind's most significant problems. While there remains another unresolved problem: the fight against infectious diseases caused by antibiotic-resistant bacterial strains. The development of protein engineering and molecular biology methods have made it possible to create in vitro a variety of molecules that closely resemble natural antigens of the immune system. One of these is catalytic antibodies (abzymes). Both natural and artificial abzymes exist [4, 9-11]. The latter are a new type of biocatalysts that belong to the immunoglobulin superfamily and contain amino acid residues in their hypervariable regions, responsible for antigen-binding, which participate in catalytic reactions.

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One of the promising directions is the creation of catalytic abzymes capable of binding to and destroying narcotic substances, blocking pathways responsible for cravings for drugs and tobacco. Another promising direction in medical practice is the development of new generation drugs for site-targeted anti-tumor chemotherapy [11].

The growing demand for vegetable oils for food and industrial purposes is driving scientific efforts to improve the characteristics of plant lipids. Developments have been made in enhancing the value of plants and the interaction of bacteria to find new ways to combat microbial infections to protect both agricultural crops and human health. To optimize the bioavailability of these biomolecules for their final valorization in food or pharmaceutical products, their stabilization by encapsulation and the kinetics of their release under physiological conditions are being studied. This is done using various approaches, from classical biochemistry to "omics" methods and the use of various biological systems, from model plants (such as of the genus *Arabidopsis* or *Sinapis*) to major oil crops.

Transgenic plants express antigens, allowing for their use for purifying recombinant proteins or for oral administration as plant-based vaccines. A variety of plants serve as expression systems, including tobacco, rice, corn, carrots, soybeans, potatoes and barley, each with its own advantages and disadvantages. Biolistic or electroporation methods are used for plant transformation, which can then be utilized in the development of vaccines against such bacterial pathogens as *Mycobacterium tuberculosis*, *Bacillus anthracis*; viral diseases such as human papillomavirus, human immunodeficiency virus, and also conditions such as cancer, synucleinopathies, or atherosclerosis [4]. Transgenic plants that produce recombinant proteins-stimulators of the immune response against tuberculosis have been created.

Another novel approach is molecular imprinting, a method for obtaining "molecular imprints" based on the polymerization of functional monomers in the presence of specially introduced template molecules. Molecular recognition underpins many biological processes. A primary focus in biotechnology is the development of synthetic recognition of molecules and systems that are specific to the ligand of interest. One branch of molecular design involves the synthesis of molecules with a specific stereochemical structure, designed to recognize and interact with a particular ligand. In contrast, molecular imprinting is a method of constructing a molecule that has specific recognition properties, due to the fact that the ligand itself directs the assembly of the desired structure. The post-genomic era is marked by the emergence of other "omics" systems aimed at identifying, studying and altering cellular components, their pathways and interactions under various conditions, including pathological ones [19, 20].

Metabolomics is one of the newest sciences within the "omics" system (named after the endings of their English names - i.e. genomics, proteomics, metabolomics, etc.). Biomarkers of pathological processes in the body encompass a wide range of characteristics, which are used as indicators of the state of the organism, overall. Among these, genetic and biochemical markers occupy a special place. According to the Human Metabolome Database HMDB (The Human Metabolome Database, https://hmdb.ca), there are at least 114,190 low-molecular-weight biochemical markers – metabolites – in humans [20].

Achievements of geneticists in the field of CRISPR-Cas9 technologies, also known as "molecular scissors", allow for cutting DNA at specific locations. In the future, this will enable an understanding of how, for example, heart tissue in the area of myocardial damage can be restored or reprogrammed. That is, to "turn on" genes to force one type of cell, which is undesired, to become another type – a necessary one. For example, cardiomyocytes. However, the other side of these technologies – their impact on human germline cells and the potential for irreversible alterations to the human gene pool – raises profound ethical concerns regarding unintended consequences for future generations, the concept of human identity, and the potential for exacerbating social inequalities through "designer babies." [18]

For the widespread application of metabolomics, scientists are trying to investigate metabolic changes in both physiological and pathological states using proteomics or transcriptomics. For example, in the event of a disease, changes in the proteome or transcriptome occur much more slowly than changes in the metabolome. Gene expression data from mRNA and proteomic analysis do not always provide information about what is happening in the cell. Metabolite profiling, in turn, shows changes in both the proteome and the genome, and is a more accurate approximation of the organism's phenotype in a healthy state and during pathology. The polymorphism of some genes is closely related to the metabolism of toxic metals in the body. An example of such genes is the gene encoding aminolevulinic acid dehydratase (ALAD), whose function is associated with the accumulation of lead in the human body. Detoxification genes include the glutathione S-transferase superfamily - GSTM. Glutathione-mediated detoxification plays a key role in ensuring cell resistance to lipid peroxidation, free radicals, protein alkylation, and in preventing DNA "breaks". Genes encoding enzymes involved in detoxification phases are "environmental genes" (alcohol dehydrogenase) and trigger genes (GSTM1, NAT2, ALAD). An example of a receptor gene is the vitamin D receptor (VDR) gene, which is involved in regulating serum calcitriol levels (calcium metabolism) and affects lead levels and circulating osteocalcin levels [13]. The presence of calcium in the coronary arteries, which carry blood to the heart, is often an alarming signal - an early indicator of coronary heart disease (CHD). Interestingly, calcium accumulation is linked not only to diet or lifestyle, but also to our genes. In fact, 30-40 % of the risk is due to our genetics.

The question of prolonging human life and rejuvenation has long been of interest to mankind. Recently, geneticists have discovered that the genome of the jellyfish *Turritopsis dohrnii*, known as the "immortal jellyfish", possesses molecular genetic mechanisms for rejuvenation. Its genome was sequenced and compared with the genome of *T. Rubra* (a related species of jellyfish with a normal life cycle). Researchers found that, compared to its relative, the "immortal jellyfish" has twice as many genes related to DNA repair and protection. The authors also found differences in several other genes, including those related to replication and stem cells. The "immortal jellyfish" has mutations that preserve telomeres – DNA sequences at the ends of chromosomes that usually shorten with age. These differences may be the key to extending life [14].

It must be noted that a large number of achievements in biotechnology and biomedicine are occurring at the nanoscale. The field of nanotechnology holds particular significance in the concept of NBIC-convergence, as these technologies enable targeted manipulations at the atomic and molecular levels. The modern development of nanomedical and biological innovations creates new approaches for the detection and treatment of diseases, targeted drug delivery, and the restoration or replacement of body parts using a wide variety of nanomaterials. Newly created sensors and computers will improve a person's ability to judge the condition of their personal health and their environment, including potential external threats and chemical contamination. In this regard, the question arises about the need to clarify the biokinetics of metals in a living organism and the mechanisms of interaction of metal nanoparticles (NP) and protein molecules.

As figuratively expressed by Academician Yu. I. Kundiiev: "Bioethics is an organic combination of modern achievements of science and medicine with spirituality", "a sign of a democratic society". Bioethics encompasses a wide range of socio-economic, moral, ethical and legal problems, the content and depth of which are constantly changing with the progress of biology, medical science and practice [1].

The fantastic possibilities of genetic engineering have given hope to the idea that they will be able to solve a number of humanity's social problems. If starting from the idea of the dominant role of the latest technologies in modern society and the notion that genes have a greater influence on the behavior of both individuals and groups of people than the environment, then it can be concluded that biotechnology plays a certain regulatory role in human behavior. Therefore, bioethical issues extend far beyond science - into the realm of socio-cultural and worldview problems.

Genome editing of somatic cells can be aimed at correcting genetic diseases, but genome editing of reproductive cells (editing of germline cells - eggs, spermatozoa and embryos) can be aimed at significant changes to humans as a species, which is dangerous for humanity. The fantastic idea of some scientists to use such new technologies to create new species can significantly impact humanity as a whole, and it is unknown how far and in which direction this process will go.

Therefore, the problem of intervention at the genetic levels means choosing between two mutually exclusive possibilities of preserving life. The first is the biological improvement of the human gene pool. This could lead to changes that will affect personal identity. The second is "non-intervention": that is, preserving human individuality, without deliberately attempting to correct the biological plane. Comparing these paths means comparing their value orientations. On the one hand, the path correcting human biology at the genetic level is based on the desire to help humanity. On the other hand, the path that harms a person the least is to be prioritized.

Ethical problems arise because, in principle, biotechnology has no limits - any manipulation is possible to solve research problems (table 1).

Table 1

Advantages and disadvantages of using modern biotechnology in medicine

Advantages	**Disadvantages**
Receiving medication (insulin, somatostatin, somatotropin, interferons)	Ethics of the use of animals for research purposes
Creation of recombinant hepatitis B vaccines, human papilloma virus, Covid-19	Violation of a human's right to life in the case of intervention at the genetic level in embryos
Genetic testing to determine predisposition of newborns to hereditary diseases	Violation of medical confidentiality as to the source of donor organs
Tissue and organ cultivation for transplantation and to treat injuries after accidents	Religious and cultural taboos, especially those that prevent women from controlling the reproduction
HIV treatment via removal of the virus from afflicted immune cells	The ethics of euthanasia – the artificial termination of life before the moment of its natural conclusion
Treatment of congenital diseases by replacing defective genes with normal ones (sickle cell anemia, hemophilia)	The occurrence of drug-resistant viruses and bacteria, which in turn can generate outbreaks of new epidemics
Solving reproductive problems for couples that are unable to have children	Certain social classes of the population are unable to reap the benefits of the advancements of modern biotechnologies
Reduction of mortality, prolonging life expectancy	Violation of natural biodiversity, a person's right to self-sufficiency and human identity by changing the genes
Safe and effective family planning	Unexpected effects on the organism, risks of health impairment

Research results and their discussion. The main ethical aspects and prospects for the implementation of biotechnology, nanotechnology and information technology (IT) in medicine are extremely important for ensuring responsible and safe progress in healthcare. Four key bioethical principles are applied to regulate these technologies, namely: autonomy: respect for the patient's right to make decisions about their own health (informed consent); non-maleficence: the obligation to minimise harm and risks; beneficence: acting in the best interests of the patient; Justice: Ensuring equal access to the latest medical advances.

Classical biotechnology is associated with fermentation processes, which are defined as operations in which microorganisms such as bacteria, fungi, yeast and certain enzymes are used to obtain biotechnological products. Traditionally, these processes have exploited the general property of microorganisms to convert substrates (e.g., glucose and oxygen) into products such as ethanol, organic acids (citric, lactic), amino acids (lysine, glutamic acid) and antibiotics (penicillins, cephalosporins) [21].

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Recombinant DNA technology is also being used more and more every year. The discovery of this method has opened up new opportunities for the development of a wide range of biopharmaceuticals that modify microorganisms, animal and plant cells to produce useful substances for medical use [21]. Biotechnology is a good alternative tool for developing active ingredients that can slow down the ageing process. The pharmaceutical and cosmetics industries have used biotechnological processes to develop many peptides that play an important role in the synthesis of the extracellular matrix, pigmentation, and innate immunity.

The technology of incorporating medicinal substances into nanocapsules allows the use of many medicinal compounds whose transport to organs and tissues would be difficult due to their insolubility in water or instability. Liposomes (nanosomes) can encapsulate aqueous solutions of medicinal substances, while polymeric nanocapsules usually contain fat-soluble compounds; thus, this technology reduces toxicity and achieves the desired pharmacokinetics for medicinal products. Currently, approaches are being developed for transporting metal and semiconductor nanostructures in nanocapsules, as well as superparamagnetic nanoparticles for selective cell destruction by electromagnetic heating, which is important for the treatment of a number of tumours [21]. A number of medicinal substances are also produced in the form of microcapsules: vitamins, antibiotics, anti-inflammatory, diuretic, cardiovascular, anti-asthmatic, hypnotic and other drugs. Another promising bionanotechnology is the transport of nanocapsules inside erythrocytes or bacteria. One of the difficulties in using nanocapsules as targeted transport for drugs is the question of their control.

Today, many companies produce nanoparticle-based products, including DIOR (France), Este Lauder, Vichy, LEOREX TM (Israel), and WGN Corporation (Japan). The ELYSEE French Cosmetology Centre uses a new mesotherapy product called CURACEN, created using molecular fractionation, which helps with age and photoaging, collagen-elastin framework issues, and lots of immune stuff (psoriasis, dermatitis, etc.). In addition, this drug is well suited for recovery after plastic surgery and chemical peels. It should be noted here that CURACEN is mainly positioned as a cosmetic and biorevitalisation product. Although its mechanism of action (growth factors, regeneration) may be beneficial for injuries, its effectiveness specifically for complex military injuries, burns and massive scars must be confirmed by high-quality clinical studies (e.g. randomised controlled trials) and not just by experience in cosmetology. Based on the stated properties of CURACEN (placental hydrolysate, which stimulates regeneration, restores skin after injuries/surgeries, has anti-inflammatory effects and helps with dermatitis/psoriasis), its potential use in the recovery of military personnel may focus on: accelerated regeneration and healing, and dermatological problems that can be exacerbated by stress, unhygienic conditions, and injuries associated with military service.

Another modern biotechnology is CRISPR-Cas9, which can be called 'molecular scissors.' A promising application of this technique is the editing of defective genes (for example, using the CRISPR-Cas9 system) to treat hereditary diseases (cystic fibrosis, sickle cell anaemia). They allow DNA to be 'cut' at a specific location, for example in the heart. In the future, this will make it possible to understand how, for example, heart tissue can be restored or reprogrammed in the area of myocardial damage. That is, to 'turn on' genes so that one type of cell becomes another — for example, cardiomyocytes. Therefore, the promising aspect here is the possibility of developing new drugs and treatments tailored to the individual genetic profile of the patient.

Today, the vast majority of the scientific community supports the use of CRISPR-Cas9 for treating serious diseases in somatic cells, but opposes germline editing for non-therapeutic purposes due to significant ethical and safety risks for future generations [18, 21]. International regulatory restrictions and positions on human germline editing (i.e., making genetic changes that are inherited) are quite strict and uniform in most developed countries (including the EU, the UK, the US, the WHO, and China since 2019). One of the most important documents in Europe is the Protocol to the Oviedo Convention (1997) on the prohibition of human cloning and heritable genetic modifications, which clearly prohibits any intervention aimed at changing the genome of offspring.

This is a very important clarification, as the ethical framework for somatic gene therapy (where genetic changes only affect the patient's body cells and are not passed on to offspring) is fundamentally different from that for germline editing. Unlike germline editing, somatic gene therapy is generally more ethically acceptable and comparable to organ transplantation or new pharmacological methods. It focuses on the principles of beneficence (the desire to benefit the patient) and non-maleficence. Since most antibodies recognise their protein antigen using a conformational or structured epitope (as opposed to a linear epitope, which is commonly used for molecular imprinting), molecular modelling of proteins is now used to develop new drugs based on abzymes [8, 10]. The use of synthetic antibodies based on molecularly imprinted polymer nanoparticles (MIP-NPs) for the recognition and binding of the highly conserved and specific peptide motif SWSNKS (3S), an epitope of glycoprotein 41 (gp41) of the human immunodeficiency virus type 1 (HIV-1) envelope. The resulting template peptide corresponds to a cyclic structure.

The use of nanoparticles is promising but, in some cases, causes concern. Targeted drug delivery: nanocontainers that deliver drugs directly to target cells (e.g., cancer cells), reducing side effects. Nanodiagnostics: Development of highly sensitive, fast and inexpensive sensors for the early detection of diseases (in particular, cancer). Regenerative medicine: Use of nanostructured scaffolds to support cell growth and tissue regeneration.

Risks associated with nanoparticles entering the environment and interacting with the human body (toxicological risks, unknown long-term effects). Future ethical issues related to the use of nanorobots inside the body, including questions of human identity and possible 'enhancement' of human functions. Another ethical aspect is preventing a situation where only the wealthy have access to advanced and expensive nanomedical treatments.

The use of modern IT technologies to artificially create human skin, tissues and internal organs sounds like science fiction at first glance, but science does not stand still, and therefore more than half of what has been described already exists in our lives. In diagnostic centres and hospitals around the world, advances in 3D printing and bioprinting are providing new opportunities for diagnosis, treatment and scientific research [6, 21]. In the coming decades, bioprinting may become one of the most important components of medicine.

Thus, in healthcare, the combination of nanotechnology with genetic engineering, artificial intelligence-based diagnostics and biosensors raises issues of privacy, consent and data security. The high cost of research, development and production traditionally poses one of the most significant challenges to the implementation and public use of nanomedicine, further affecting its accessibility, especially in low- and middle-income countries.

The implementation of ethical principles that promote accountability, a thousand effective ways to combat strict data privacy laws and transparency in the regulatory system will greatly help to allay fears and ensure the responsible development and application of nanomedical technologies.

Conclusions. Since science aims to achieve certain results that can be used both for the benefit of a humanity and against it, the more significant scientific discoveries become, the more urgent the issue of bioethics becomes. It should be noted that the large number of achievements in biotechnology and variety of nanomaterials, create new approaches for detecting and treating diseases (genetic, oncological, addictions and others). Primarily, these advancements raise questions of ethics regarding the preservation of humans as a species. At the same time, bioethical aspects of the use of micronutrients, particularly transgenic plants capable of influencing the regulation of metabolic processes and normalizing the functions of individual organs and systems, must be considered and controlled after all unexpected and undesirable long-term effects on the organism are determined.

All discussed above is grounded in the following key bioethical considerations: protecting the right to life in the application of assisted reproductive technologies, in vivo fertilization, in vitro fertilization, preimplantation genetic diagnosis and embryo selection, homologous fertilization, heterologous fertilization and surrogate motherhood, prohibition of human cloning in international law, the impact of human genome modification on human dignity and rights, euthanasia and the protection of the right to life in international law, which must be taken into accounts by specifically by scientists in the course of their research and by mankind as a whole as we progress into the technological future.

Prospects for further research. The direct consequences of modern biotechnology and nanotechnology in the medical field raise questions about innovation and patient safety, accessibility and fairness (these methods can be expensive), and safety due to insufficient research into the long-term consequences and risks of side effects. For example, in healthcare, the combination of nanotechnology with genetic engineering, artificial intelligence-based diagnostics and biosensors raises questions about confidentiality, transparency of safety assessments and clinical trials. There are concerns that the future of modern biotechnology could genetically alter humans with unpredictable consequences. The introduction of ethical principles that provide for responsibility, confidentiality, and transparency of the regulatory system will greatly contribute to the responsible development and application of modern biotechnologies in both nanomedicine and genetic engineering.

Conflict of interest: absent.

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ЕТИЧНІ АСПЕКТИ СУЧАСНИХ БІОМЕДИЧНИХ ТЕХНОЛОГІЙ: ЧИ Є КОНВЕРГЕНЦІЯ НАУК БЛАГОМ ДЛЯ ЗБЕРЕЖЕННЯ ЛЮДИНИ ЯК ВИДУ?

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Резюме. Сучасні біотехнології, генна інженерія та нанотехнології, прагнучи покращити життя й продовжити його тривалість, ставлять перед суспільством нові етичні виклики. Біоетика має визначити моральні межі втручання в живий організм, розмежовуючи терапевтичне використання (корекція аномалій) та покращення людини «заради покращення».

У статті підкреслено конвергенцію NBIC-технологій (нано-, біо-, інфо- та когнітивних), які взаємодіють для підвищення якості життя. Наводяться приклади біоінспірації та біомімікрії: від авіаційних крил до гідрофобних поверхонь, а також застосування біоміметичних наноматеріалів в імплантології та доставці ліків. Природні біоактивні сполуки розглядаються як альтернатива синтетичним.

Особлива увага приділяється каталітичним антитілам (абзимам), котрі є перспективними у лікуванні залежностей та онкології, а також використанню трансгенних рослин для розробки вакцин. Обговорюється молекулярний імпринтинг та «оміксні» системи, зокрема метаболоміка як точніший індикатор фізіологічного стану. Генетичні поліморфізми пов'язують із метаболізмом токсичних речовин та ризиком захворювань.

Дослідження геному «безсмертної медузи» відкривають шляхи до розуміння механізмів омолодження. Попри те, що технологія CRISPR-Cas9 обіцяє революційні зміни в медицині (наприклад, відновлення серцевої тканини), вона водночас несе потенційні ризики неконтрольованих змін геному, особливо під час втручання в репродуктивні клітини. Це викликає дискусії про право на життя, конфіденційність та доступність новітніх методів.

Підсумовуючи, наукові прориви у біотехнологіях для діагностики та лікування генетичних, онкологічних захворювань та залежностей вимагають ретельного етичного осмислення та контролю для збереження людини як виду та уникнення непередбачуваних наслідків. Захист права на життя та гідності людини має бути пріоритетом у застосуванні цих потужних інструментів.

Ключові слова: біоетика, конвергенція наук, генна інженерія, імпритинг, біотехнологія, транскриптоміка, метаболоміка, омікс-технології.

Конфлікт інтересів: відсутній.

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