Lecture 14. Personalized medicine (the future of medicine).

Learning outcomes:

1. Give the definition to the terms “personalized medicine”, “gene therapy”, “target delivery”, “nanoparticles”, “nanotechnology”.
2. Explain how the omics technologies can be used for individual diagnostics, treatment and profilactics of human diseases?
3. Analyze the modern and future methods of biomedicine used for treatment of human diseases (nanotechnology, biocompatible polymers, artificial tissues and organs, using the stem cells, radiation oncology and etc.). What are their dangers and perspectives?
4. Characterize the methods of gene therapy “*ex vivo”* and *“in vivo”*, give the specific examples.
5. Analyze the perspectives and dangers of human genome editing, its bioethical consequences.

Personalized medicine, also referred to as **precision medicine**, is a medical model that separates people into different groups—with medical decisions, practices, interventions and/or products being tailored to the individual patient based on their predicted response or risk of disease. The terms personalized medicine, precision medicine, **stratified medicine** and **P4 medicine** are used interchangeably to describe this concept though some authors and organisations use these expressions separately to indicate particular nuances.

While the tailoring of treatment to patients dates back at least to the time of **Hippocrates**, the term has risen in usage in recent years given the growth of new diagnostic and informatics approaches that provide understanding of the molecular basis of disease, particularly genomics. This provides a clear evidence base on which to stratify (group) related patients.

Among 14 Grand Challenges for Engineering, initiative sponsored by National Academy of Engineering (NAE), personalized medicine has been identified as a key and prospective approach to “**achieve optimal individual health decisions**”, therefore overcoming the challenge of “Engineer better medicines”.

In personalised medicine, **diagnostic testing** is often employed for selecting appropriate and optimal therapies based on the context of a patient's genetic content or other molecular or cellular analysis. The use of genetic information has played a major role in certain aspects of personalized medicine (e.g. **pharmacogenomics**), and the term was first coined in the context of genetics, though it has since broadened to encompass all sorts of personalization measures, including the use of **proteomics**, **imaging analysis, nanoparticle-based theranostics**, among others.

Targeted drug delivery, sometimes called **smart drug delivery**, is a method of delivering medication to a patient in a manner that increases the concentration of the medication in some parts of the body relative to others. This means of delivery is largely founded on nanomedicine, which plans to employ nanoparticle-mediated drug delivery in order to combat the downfalls of conventional drug delivery. These nanoparticles would be loaded with drugs and targeted to specific parts of the body where there is solely diseased tissue, thereby avoiding interaction with healthy tissue.

Nanotechnology or **nanotech** is the use of matter on an **atomic, molecular, and supramolecular scale** for industrial purposes. The earliest, widespread description of nanotechnology referred to the particular technological goal of precisely manipulating atoms and molecules for fabrication of macroscale products, also now referred to as molecular nanotechnology. A more generalized description of nanotechnology was subsequently established by the National Nanotechnology Initiative, which defined nanotechnology as the manipulation of matter with at least one dimension sized from **1 to 100 nanometers**. This definition reflects the fact that quantum mechanical effects are important at this quantum-realm scale, and so the definition shifted from a particular technological goal to a research category inclusive of all types of research and technologies that deal with the special properties of matter which occur below the given size threshold. It is therefore common to see the plural form

"nanotechnologies" as well as "nanoscale technologies" to refer to the broad range of research and applications whose common trait is size.
Nanotechnology as defined by size is naturally broad, including fields of science as diverse as surface science, organic chemistry, molecular biology, semiconductor physics, energy storage, engineering, microfabrication, and molecular engineering. There are hopes for applying **nanorobots** in medicine. Nevertheless, progress on innovative materials and methodologies has been demonstrated with some patents granted about new nanomanufacturing devices for future commercial applications, which also progressively helps in the development towards nanorobots with the use of embedded nanobioelectronics concepts.
Gene therapy (also called **human gene transfer**) is a medical field which focuses on the utilization of the therapeutic delivery of nucleic acids into a patient's cells as a drug to treat disease. The first attempt at modifying human DNA was performed in 1980 by Martin Cline, but the first successful nuclear gene transfer in humans, approved by the National Institutes of Health, was performed in May 1989. The first therapeutic use of gene transfer as well as the first direct insertion of human DNA into the nuclear genome was performed by French Anderson in a trial starting in September 1990. It is thought to be able to cure many genetic disorders or treat them over time.
Gene therapy can be ***in vivo*** and ***ex vivo***. In biology, ***in vivo*** is often used to refer to experimentation done in a whole organism, rather than in live isolated cells, for example, cultured cells derived from biopsies. In this situation, the more specific term is ***ex vivo***. Once cells are disrupted and individual parts are tested or analyzed, this is known as in vitro.
CRISPR gene editing is a genetic engineering technique in molecular biology by which the genomes of living organisms may be modified. It is based on a simplified version of the bacterial **CRISPR-Cas9 antiviral defense system**. By delivering the Cas9 nuclease complexed with a synthetic guide RNA (gRNA) into a cell, the cell's genome can be cut at a desired location, allowing existing genes to be removed and/or new ones added in vivo (in living organisms).
The technique is considered highly significant in biotechnology and medicine as it allows for the genomes to be edited ***in vivo*** with extremely high precision, cheaply and with ease. It can be used in the creation of new medicines, agricultural products, and **genetically modified organisms**, or as a means of controlling pathogens and pests. It also has possibilities in the treatment of inherited genetic diseases as well as diseases arising from somatic mutations such as cancer. However, its use in human germline genetic modification is highly controversial. The development of the technique earned Jennifer Doudna and Emmanuelle Charpentier the Nobel Prize in Chemistry in 2020. The third researcher group that shared the Kavli Prize for the same discovery (led by Virginijus Šikšnys) was not awarded the Nobel prize.

The questions for self - control:
1. What are the “personalized medicine”, “gene therapy”, “target delivery”, “nanoparticles”, “nanotechnology”?
2. Applications of the “omics” technologies in individual diagnostics, treatment and profilactics of diseases.
3. Modern and future methods of biomedicine.
4. Gene therapy “*ex vivo”* and *“in vivo”*.
5. Technologies of genome editing and their bioethical consequences.

Recommended readings:

1. Stratified, personalised or P4 medicine: a new direction for placing the patient at the centre of healthcare and health education (Technical report). Academy of Medical Sciences. May 2015. Archived from the original on 27 October 2016. Retrieved 6 January 2016.
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