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Science Knows No Boundaries

Prof. Jacek Jemielity of the Centre of New Technologies, University of Warsaw, talks about tailor-made cancer therapies and explains what coronavirus vaccines have to do with cancer treatment.

Can you tell us a bit more about the discovery for which you received the 2021 Prize of the Foundation for Polish Science?

JACEK JEMIELITY: It's hard to talk about a single discovery for which we received the prize. Rather, this was a result of consistent efforts, many years of research into the properties of mRNA (short for "messenger ribonucleic acid") as a therapeutic agent. We should start off by saying that all proteins in the body are made in the same way, with mRNA providing a natural recipe for each of them. Proteins play an extremely important role in the human body as some of the basic building blocks for tissues. Essentially every function in a human cell, and by the same token in the whole of the human body, depends on proteins. By changing the structure of mRNA, we can improve its properties, which can be used in modern therapies.

My team and I have been working to enhance the stability of mRNA. We do so by blocking its ends using what are called caps, which has helped protect mRNA from premature degradation. Still, some enzymes can cleave these caps, thus causing mRNA to degrade. By changing literally one atom in their structure, we managed to increase mRNA's resistance to degradation by enzymes in cells. In the same process, we also improved the compatibility of mRNA with the cellular machinery responsible for making proteins. As a result, there is a chance to create mRNA that is more competitive than that which already exists in cells.

A license to the first invention that resulted from the research was bought by BioNTech, back then a little-known company that is now famous for producing the first vaccine against coronavirus. The therapeutic mRNA we developed was sublicensed to pharmaceutical companies and is currently at the stage of clinical trials involving cancer patients. In the meantime, we have been working to further improve the properties of therapeutic mRNA. For example, we have been able to achieve a similar effect as before, but one that was easier to scale up, which is very important in the practical production of therapeutics. We are currently developing this technology in collaboration with the University of Warsaw and oncologists from the Medical University of Warsaw. On the one hand, we are constantly trying to improve the therapeutic properties of mRNA; on the other, we are developing therapies that utilize it.

What are the practical applications of these discoveries?

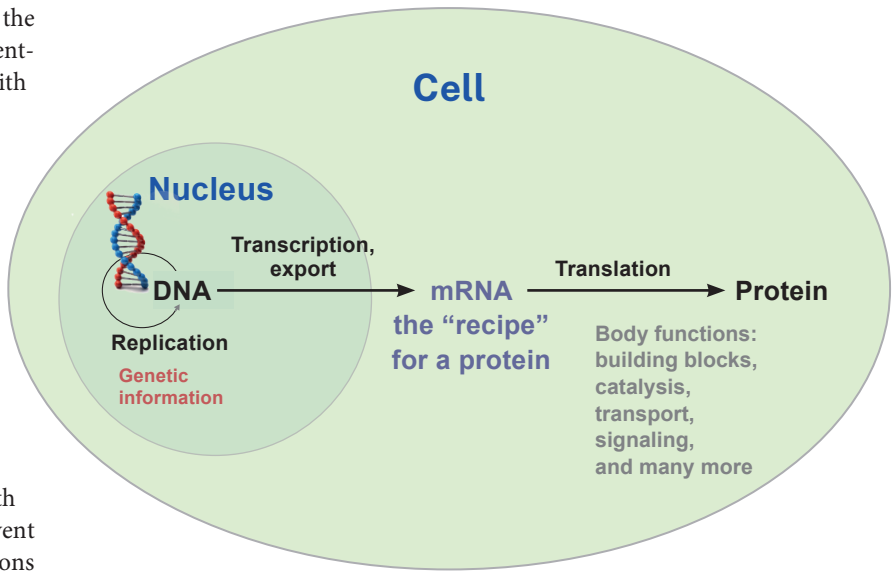
They can be used in various ways: both to prevent diseases and to treat them. The former applications include vaccines. We produce mRNA to stimulate our immune system specifically to fight and prevent cancer. As is the case with coronavirus, such vaccines are intended to prevent the development of the disease. Other applications of our discoveries surrounding mRNA include therapeutic vaccines, more specifically ones used to treat cancer. This involves giving the patient a vaccine (for example a coronavirus vaccine) that teaches the immune system to recognize anything appearing in the body with the same protein. Consequently, the virus is neutralized, there is no infection, and the disease does not develop. We want to create a similar mechanism of action for cancer cells.

Therefore, mRNA can be used to treat diseases that have already developed. In this case, it is necessary to identify a genetic difference between healthy cells and cancer cells in a given patient. If cancer-specific protein can be identified, we can teach the immune system to recognize and destroy it. Of course, in the case of cancer, the difficulty lies in the numerous defense mechanisms it has developed. Currently, there are several hundred clinical trials around the world aimed at finding ways to fight cancer. A personalized approach, or one that involves creating tailor-made vaccines, adjusted to specific mutations in the cancer cells of a specific patient, appears to be the most effective of these methods. There is also a universal approach, but it will simply produce no effects in a certain share of the population. The personalized approach is very effective.

Also, some diseases are caused by the fact that a specific protein, important for a specific process, is either not produced in the cells or is produced with deformed structure. In such cases, mRNA can be applied to supplement such missing or defective proteins. There are many rare genetic and metabolic diseases, such as cystic fibrosis and phenylketonuria, in which such therapy can be effective. Currently, there are clinical trials testing mRNA-based regenerative

Prof. Jacek Jemielity
works at the University of Warsaw's Centre of New Technologies, specializing in organic chemistry and biochemistry. He won the 2021 Prize of the Foundation for Polish Science (FNP) for developing chemical modifications of mRNA as tools for therapeutic applications and studies of cellular processes.
j.jemielity@cent.uw.edu.pl

mRNA as a genetic recipe for a specific protein



medicine to support stem cell differentiation or the use of mRNA for precise genome editing, recently a very popular technology called CRISPR-Cas9. For this method to work, the key role is played by a bacterial protein (called Cas9) that is not present in our cells. Delivering it with mRNA is the best solution and allows us to treat genetic diseases by manipulating the genome with high precision. This raises a number of ethical issues, because the same technology can also be used in human genetic engineering, or to modify the human genome to obtain desired traits (such as eye color).

What else does the Center of New Technologies at the University of Warsaw do?

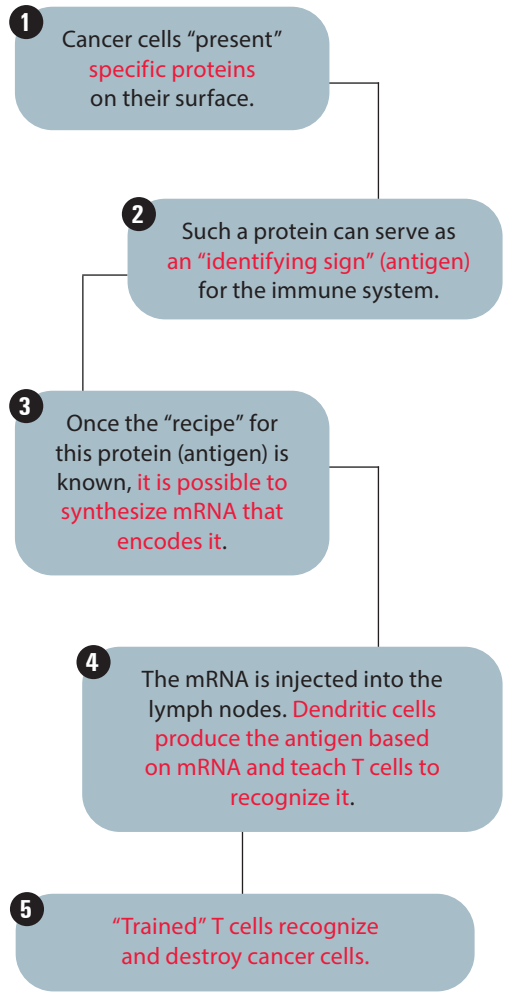
It is an interdisciplinary research unit that draws upon the work of biologists, physicists, chemists, and IT experts. The guiding concept is openness to new ideas, creating an environment open to scientific and economic development. Currently, there are about 25 research teams working at the Centre. They deal with a very wide variety of topics, ranging from quantum physics to new materials, solar energy conversion, and our research at the intersection of chemistry, biology, and molecular biology. The teams collaborate with each other on a spontaneous basis. We reach out to colleagues, scientists from other fields, for consultation and advice. This proximity of various disciplines and the similarities between various topics offer great advantages.

And what groundbreaking discoveries do you look forward to in your field? What is the "holy grail" of today's biochemistry?

What we are currently working on, namely the therapeutic application of mRNA, remains a dream. This field of science is still in its infancy, and coronavirus vaccines were the very first mRNA-based vaccines. I dream of seeing the technology we are now developing become approved for cancer treatment in the next two to three years. Clinical trials look promising, but these are still experimental studies. The goal is to have more therapies approved, and it would be great if successful ones were to be based on our inventions. I hope that mRNA research will develop in different directions, so that it could have a real impact on improving the health of many people in the world. When it comes to certain diseases, we have in a sense hit the wall. Fortunately, however, innovative methods offer new hope for their safe and more effective treatment. Another area involves cell therapies, where cells are isolated from the patient, modified in a relevant way, and then transplanted back into the patient's body. We still need years of research before such therapies can be used on a wide scale. But science knows no boundaries.

Interview by **Justyna Orłowska, PhD**

The idea behind cancer vaccines



Various applications of mRNA therapy

Antigen delivery

Cancer: dendritic cell-based immunotherapies

Vaccines against infectious diseases

Delivery of nucleases

CRISPR/Cas9 gene editing

Regenerative medicine:

– delivery of growth factors (for example in cardiovascular diseases)

– stem cell generation and modification

Supplementation of proteins and peptides

Genetic diseases, metabolic disorders