Content Unit
[Nano in medicine]

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Last processing date: [12. 12. 2021]

The topic

First introduction
Nanotechnology brings to medicine a number of possibilities inconceivable until recently. It revolutionises our approach to diagnostics and treatment of damaged tissues and various illnesses. We can leverage on unique properties of nanomaterials, e.g. the large reactive surface of nanomaterials, excellent permeability through the cell membrane, etc.

Nanorobots detect tumours, aid in gentle collection of smaller tissue samples, and deliver precise volume of therapeutic agents directly to the specified location of the health problem within the human body. Nanosilver helps eliminate bacteria that have developed resistance to antibiotics in recent decades. Other nano structures create adequate conditions for on-line monitoring and real-time diagnostics, and use electronic sensing devices to notify doctors of any needs for urgent medical intervention or changes in medication. Compared to earlier procedures, we are now able to make use of nanofiber structures for much better treatment of injuries to skin, bone and other human organs, replacement of missing or damaged tissue, and mitigation of serious injuries.

Practical relevance – This is what you will need the knowledge and skills for
In this section, you will learn about the key directions of development of nanotechnologies used in medicine as well as the possibilities that will open up in the future. At the same time, we will use the Covid-19 pandemic as an example of how nanotechnology solutions may help in prevention of respiratory diseases in healthcare facilities and elsewhere.

Overview of learning objectives and competences
In LO_Main directions of the use of nanotechnologies in contemporary medicine_01 you will learn how nanomaterials can help in drug delivery and diagnosis of many serious diseases, revolutionise tissue engineering and make a significant contribution to the eradication of bacteria that have become resistant to antibiotics. In LO_Nanotechnology in the covid-19 pandemic_02 you will receive information on the benefits of nanotechnology solutions in the development of mRNA vaccines, on the unique properties of protective equipment with a nanofiber membrane protecting the respiratory system and acting as a barrier preventing the spreading of respiratory diseases, and on the benefits of photocatalytic air purification from microorganisms in prevention of infection. In LO_Future use of nanotechnologies in medicine_03 you will learn the basics of the application of sensors with nanoelectronics; we will introduce you to the amazing world of nanorobots in medicine as well as the future benefits of nanotechnology in repairing and improving human bodies.

Learning objectives	**Fine objectives**
LO_ Main directions of the use of nanotechnologies in contemporary medicine_01: you will learn how nanomaterials can help in distribution of medicaments and diagnostics of a number of serious diseases, revolutionise tissue engineering, and significantly contribute to the struggle against bacteria resistant to antibiotics.	FO_ Targeted distribution of drugs_01_01: you can learn how to save money on expensive medicines, while reducing their side effects FO_ Diagnostics_01_02: you can find out in which areas nanotechnology excels in diagnostics and how the new diagnostics improves the preciseness of surgery FO_ Tissue engineering_01_03: you can find out why nanofiber structures are suitable for healing of skin and bone wounds FO_ Nanoparticles against antibiotic-resistant bacteria_01_04: you can discover the benefit of using nanoparticles of silver in the struggle against bacteria resistant to antibiotics
LO_ Nanotechnology in the covid-19 pandemic_02: you will receive information on the benefits of nanotechnology in the development of mRNA vaccines, on the unique properties of protective equipment with a nanofiber membrane protecting the respiratory system and acting as a barrier preventing the spreading of respiratory diseases, and on the benefits of photocatalytic air purification from microorganisms in prevention of infection.	FO_Nanotechnological solution in the development of mRNA vaccines_02_01: you will learn about the suitability of nanoparticles as vaccine media as well as the use of nanoparticles in the development of SARS-CoV-2 mRNA vaccines. FO_Respiratory protection products with nanofiber membrane_02_02: you will see the evidence for why nanofibre masks capture viruses more effectively than conventional masks. FO_Photocatalytic purification of air from microorganisms_02_03: you will learn how photocatalytic nano coating cleans itself as well as the air around from organic contaminants, including microorganisms

LO_ Future use of nanotechnologies in medicine_03: you will learn the basics of the application of sensors using nanoelectronics; we will introduce you to the amazing world of nanorobots in human medicine as well as the future benefits of nanotechnology in repairing and improving human bodies.	FO_Sensors using nanoelectronics_03_01: you will learn about the benefits of sensor nanoelectronics in medicine and the latest trends of in its application FO_Nanorobots_03_02: you will have the opportunity to compare microrobots with nanorobots and discover their benefits and control methods; FO_ Repair and improvement of human bodies_03_03: you will learn how nanomedicine can extend human life and whether it is advantageous to use nanotechnology to improve existing human capabilities.

• Build knowledge - The principals of the main directions of the use of nanotechnologies in contemporary medicine

Targeted distribution of drugs

Nanotechnology has provided healthcare specialists with the ability to deliver drugs to a specific location within the body using nanoparticles. This significantly reduces the quantity of drugs needed, while reducing side effects. First, the drug is encapsulated, then delivered to the target area of the body, and finally released. Nanoparticles can penetrate the cell membrane. Safe entry into cells is an important step in achieving high therapeutic efficacy. Treatment is then triggered by a certain signal, e.g. a magnetic field, activating rays of a defined wavelength, etc. Administration of drugs using nanotechnology is currently the dominant direction of nano development in medicine.

Definition
Nanoparticles Nanoparticles are commonly defined as particles of 1 to 100 nanometers in diameter. Particles of this size can penetrate the cell membrane – therefore, they are subject to strict safety regulations. While the ability of nanoparticles to penetrate the cell membrane may be seen as adversary in many areas, it can be used with great success in medical treatment.

Example
Silica can trigger a catastrophic production of oxygen radicals in a cancer cell, causing such cell to die. The team of scientists lead by Dalton Tay of Nanyang Technological University, Singapore, coated silica nanoparticles of 30 nanometers in diameter with L-phenylalanine – one of the essential amino acids that the human body cannot synthesise but needs them. Therefore we must take phenylalanine through our diet, usually from meat or milk products. Phenylalanine is also essential for tumour cells, which is why they accept it willingly. However, with phenylalanine they also receive a silica nanoparticle as a 'Trojan horse'. The newly created silica nanoparticles with molecules of phenylalanine target exclusively the tumour cells, while not requiring any external activating impulse. They kill about 80 % of aggressive breast, skin, and stomach tumour cells.

Diagnostics

Nanotechnology brings sensitive and extremely accurate diagnostic tools. The small size of nanoparticles delivers properties that may be highly useful in imaging, particularly in oncology. Quantum dots, i.e. nanoparticles with quantum confinement properties such as light-size adjustable emission, can produce tumour images in combination with magnetic resonance. When exposed to ultraviolet light, nanoparticles glow. When injected, they seep into cancer tumours. The surgeon can see the glowing tumour, using the image as a guide to remove the tumour more accurately. The nanoparticles glow much brighter than organic dyes and they require a single source of light. Fluorescent quantum dots produce a higher-contrast image at a price lower than that of organic dyes commonly used as contrast media. In the recent years, scientists have discovered that nanocrystals can enable them to study cell processes on the level of single molecules. This can considerably improve diagnostics and treatment of cancer.

Definition
Quantum dot Quantum dot is a confined area of a semiconductor of about 30 nm in diameter and 8 nm in height, capable of binding electrons due to its lower energy compared to the conduction band of the surrounding semiconductor. The electrons can only take on discrete energy values similarly to the atom. Quantum dots are used in special components capable of working with singular electrons or photons.

Example
Nanodiamonds are about 5 nanometers in size. If their internal structure is modified, they can be used to diagnose diseases – including cancer. They act as miniature sensors that can be placed inside cells. We can measure e.g. temperature and acidity or detect the presence of certain crucial chemical substances. Nanocrystals can provide information about the surrounding environment only if their lattice is disturbed intentionally. The crystal lattice of a nanodiamond may be imagined as a carton of eggs. Each of the eggs represents a single atom of carbon, and if one of the atoms is knocked out, the optical properties of the material change completely. Neutrons shoot the boron nucleus which subsequently breaks into nuclei of lithium and helium. The particles act as a hand that rips the atom out of the crystal lattice. After additional modification, the crystals can fluoresce. And they can act as a sensor that can be used by doctors to detect tumours. It should also be noted that carbon as an element is naturally present in our bodies, i.e. it is not a foreign substance to the human organism. Thanks to that, nanodiamonds can replace other contrast substances and become a perfect alternative.

Tissue engineering

New nanofiber structures allow for better healing of skin wounds and bone fractures. Wounds heal up to tens of percent faster compared to existing treatment methods; the structure of the filling in damaged bones is a lot more robust, almost identical to that of the original bone, and damaged skin shows a lot less scarring in the end. The nature of nanofiber layers is very similar to that of the intercellular substance. As a result, new cells can grow successfully on nanofiber structures. Therefore, the range of biocompatible and biodegradable substances used for production of nanofibers for medical purposes continues to grow. The new generation of nanofibers will find its use primarily in treatment of developmental defects, complicated splinter fractures, extensive burns, and abrasions. In addition to better healing, complicated cases of damaged skin and bone also show a lot less subsequent complications and a lower percentage of reoperations. Two-component nanofibers not only improve the quality of treatment, but also improve the efficiency of the treatment significantly. Nanoparticles like graphene, carbon nanotubes, etc. are used as reinforcement in production of strong biodegradable nanocomposites for the application for bone tissue. These nanocomposites are used as a new, mechanically strong, lightweight composite material for bone implants.

Definition
Biocompatibility A material is biocompatible, if it does not induce any negative reaction in the organism. **Biodegradability** Biodegradation is a process of natural decomposition of a substance using natural biologic processes. Almost any material is biodegradable, but the time needed for decomposition in a natural environment can vary. The highest demands for the rate of decomposition are placed on a material that should biodegrade in a human body.

Example
A team of chemists led by Samuel Stupp of Northwestern University in Evanston, US developed nanofibers that accelerate the healing process. The fibers are based on amphiphilic peptides (i.e. peptides having both hydrophilic and lipophilic properties). When injected into the organism, amphiphilic peptides form long nanofibers that attached their ends onto the wounded spot. Stupp also equipped amphiphilic peptides with a sequence of eight amino acids that bind heparin. Molecules of heparin are extremely 'sticky'. Heparin binds growth factors responsible for repair and growth of blood capillaries in the wound.

Nanoparticles against antibiotic-resistant bacteria

The numbers of multi-drug resistant microbes have been growing since the invention of antibiotics. This opened the room for new technologies using nanoparticles of silver that can destroy bacteria reliably. When treated with nano silver, numbers of bacteria in wounds drop by four to five orders in just 24 hours, which may not be achieved with antibiotics. The target is for the nanoparticles of silver to kill microorganisms, but not to settle in the patient's body. When applied to the wound, nanoparticles of silver should remain bound to the respective medium inseparably. If the nano silver is coherently bound e.g. to a polymer in the nanofibers of a non-woven textile, it will fulfil its antibacterial function to be removed later together with the nanofiber membrane. The nanofiber membrane in the wound dressing is permeable for molecules of air, but it will keep out microorganisms and other adverse substances.

Definition
Coherence Coherence (lat. co-haereo, keep together) means cohesion, either physical or logical. In this context, coherent means cohesive, well-ordered, non-separable.

- # Save knowledge

Summary

You reached the end of the content unit about **Main directions of the use of nanotechnologies in contemporary medicine.** As there was a lot to learn, please receive a quick repetition of the most important things you learned about this topic:

Nanotechnology has provided healthcare specialists with the ability to deliver drugs to a specific location within the body using nanoparticles. This significantly reduces the quantity of drugs needed, while reducing side effects. Nanoparticles can penetrate the cell membrane. Treatment is then triggered by a certain signal, e.g. a magnetic field, activating rays of a defined wavelength, etc.

Nanotechnology brings sensitive and extremely accurate diagnostic tools. The small size of nanoparticles delivers properties that may be highly useful in imaging, particularly in oncology. Quantum dots can produce tumour images in combination with magnetic resonance imaging. Nanoparticles glow when exposed to ultraviolet light. When injected, they seep into cancer tumours. The surgeon can see the glowing tumour, using the image as a guide to remove the tumour more accurately.

New nanofiber structures allow for better healing of skin and bone wounds. Wounds heal up to tens of percent faster compared to the existing treatment methods; the structure of the filling in damaged bones is a lot more robust, almost identical to that of the original bone, and damaged skin shows a lot less scarring in the end. The nature of nanofiber layers is very similar to that of the intercellular substance. As a result, new cells can grow successfully on nanofiber structures.

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The topic

Build knowledge - The principals of the nanotechnology in the covid-19 pandemic

Nanotechnological solution in the development of mRNA vaccines

Nanoparticles can be used as vaccine carriers. They protect the vaccine, giving it time to trigger a stronger immune response. Thanks to a nano solution, Pfizer/BioNtech and Moderna have developed the first vaccines using messenger RNA (mRNA) against the SARS-CoV-2 virus. The new class of DNA and RNA based vaccines provides nano platforms with a genetic sequence of specific viral proteins for host cells. Traditional vaccines instead trigger the immune response upon injection of whole viruses into the body, be it attenuated live viruses, inactivated viruses, or artificial ones. mRNA based therapies offer a number of benefits compared to other methods. Delivery of mRNA is safer than delivery of a whole virus or DNA, as mRNA is not infectious and it cannot be integrated into the host genome; DNA needs to reach the decoded nucleus, while mRNA is processed directly in the cytosol (one of the liquids found inside cells); mRNA has a short half-life that can be regulated by molecular design; and finally, it is immunogenic (provokes an immune response so the body can defend itself), which may be beneficial in vaccine design, but the immunogenicity can be modulated by molecular engineering techniques. However, for mRNA to be safely and effectively transported in vivo (in whole, living organisms or cells) without degradation in the circulation and to reach the cytosol through the cell plasma membrane, it needs a carrier. For a lot of mRNA-based therapeutics, lipid nanoparticles are the carrier of choice.

Definition
mRNA in a lipid nanoparticle Molecules of mRNA are unstable in a human organism and if injected directly into the body, they would degrade rapidly. Therefore, lipids are used to protect the mRNA, combining with mRNA into lipid nanoparticles. Upon injection into the body, lipid nanoparticles merge with the cell membrane, releasing the mRNA into the cytoplasm.

Example
Vaccines are tasked to train the immune system to recognise the part of the virus responsible for triggering the disease. Traditional vaccines contain either attenuated virus or proteins thereof. Instead, a mRNA contains a ribonucleic acid that codes the virus protein. Following the vaccine application, muscle cells use the injected mRNA as a 'template' or 'matrix' to synthesise a part of the spike protein of the SARS-CoV-2 virus.

Respiratory protection products with nanofiber membrane

Since 2020, we have seen extended use of nanofiber membranes as protection of the human respiratory system in medical masks and respirators. The nanofiber material significantly improves the filtration efficiency (capture rate) of nano masks and nano respirators, in particular with regard to the smallest particles. A significant proportion of conventional medical masks and respirators use electrostatically charged microfibre structures (meltblown, spunbound, etc.) as the main filtration medium. The electrostatic charge in the non-woven textiles aids significantly in capturing the particles. However, the charge in conventional medical masks gets discharged due to humidity in the user's breath and due to humidity commonly present in air. The 100% humidity in the area between the user's mouth and a common medical mask or respirator reduces the filtration efficiency of such a mask or respirator by tens of percent in just two hours. Nano masks and nano respirators do not rely on filtration based on electrostatically charged microfibres. Thanks to that, their filtration efficiency (capture rate) remains constant.

Definition
Nanofiber membrane Nanofiber membrane is a very fine non-woven textile of nanofibers. The average diameter of nanofibers is typically in the range between 200 to 500 nanometers. The average size of pores between the nanofibers in the filtration layer of a nano mask is commonly in hundreds of nanometers and it exceeds the fiber diameter several times. However, the nanofiber layer is composed of a great number of sub-layers, meaning that the largest pores are covered by another layer. Thanks to that, the resulting efficiency in capturing particles equal in size to the average size of pores in the nanofiber layer is significantly higher than that of the largest pores in a single layer. The porosity of the nanofiber membrane plays an important role. The pores between nanofibers account for 85 to 90% of the membrane volume. The combination of a high number of pores and their small size makes the nanofiber filter highly breathable, while ensuring excellent efficiency in capturing particles, including viruses and bacteria.

Photocatalytic purification of air from microorganisms

In the process of photocatalysis, titanium dioxide converts the UV component of light into energy purifying air from organic contaminants including toxic gases, fungi, viruses, and bacteria. It decomposes them into molecules of water, carbon dioxide, and harmless minerals. Indoor, where there is a high probability of presence of infected people, photocatalytic air purification can reduce concentrations of viruses and bacteria significantly. This reduces the risk of infection for people in the room. Titanium dioxide works even more efficiently, if used in nanocrystalline form. Nanocrystals of titanium dioxide have a large reactive surface and therefore, they can purify a larger volume of air. The UV component of light excites the electrons in the nanocrystals of titanium dioxide, which then in turn decomposes the contaminants. There are binding agents in self-cleaning functional coating that can anchor nanocrystals of titanium dioxide reliably, while pushing them to the surface of the coating. This ensures that the coating performs the purifying function with the highest possible efficiency.

Definition
Photocatalysis Photocatalysis is the process of chemical decomposition of substances using a photocatalyst and rays of light. The use of photocatalysis is basically twofold: Self-cleaning – thanks to photocatalysis, the surface of the material is resistant to the development of organic contaminants, thus retaining its original appearance and colour in long term Purification of the surrounding medium – polluted air or water, allowing to suppress some adverse effects of human activity, e.g. air pollution by organic contaminants, including microorganisms.

If the interior does not allow for application of a photocatalytic coating with nanocrystals of titanium dioxide on the walls and the ceiling, it is possible to use solitary nano air purifiers using the same principle of photocatalysis as a smart coating. A propeller blows polluted air into a tunnel with filters containing nanocrystalline titanium dioxide and UV lamps, while purified air is released back into the room. Classic HEPA filters in air-condition vents only provide for full efficiency in capturing fine contaminants for just a few weeks after replacement, nano filters in air-condition vents guarantee such efficiency for many years thanks to photocatalytic purifiers. In addition to that, they do not require any maintenance as they are self-cleaning.

- # Save knowledge

Summary

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A nanofiber membrane significantly improves the filtration efficiency of nano masks and nano respirators, in particular with regard to the smallest particles. A significant proportion of conventional medical masks and respirators use electrostatically charged microfibre structures as the main filtration medium. Nano masks and nano respirators do not rely on filtration based on electrostatically charged microfibres. Thanks to that, their filtration efficiency remains constant.

In the process of photocatalysis, titanium dioxide converts the UV component of light into energy purifying air from organic contaminants including toxic gases, fungi, viruses, and bacteria. Indoor, photocatalytic air purification can reduce concentrations of viruses and bacteria significantly. This reduces the risk of infection for people in the room. Titanium dioxide works even more efficiently, if used in nanocrystalline form. Nanocrystals of titanium dioxide have a large reactive surface and therefore, they can purify a larger volume of air.

The topic

- # Build knowledge - The principals of the future use of nanotechnologies in medicine

Sensors using nanoelectronics

Thanks to nanotechnology, particularly nanoelectronics, healthcare will soon go through deep changes by using the traditional strengths of the semiconductor industry – miniaturisation and integration. While conventional electronics has found a lot of applications in biomedicine – medical monitoring of vital signals, biophysical studies of tissue irritants, implanted electrodes stimulating the brain, pacemakers, and limb stimulation – the use of nanomaterials will result in further push towards implantation of electronics in the human body.

Definition
Nanoelectronics Nanoelectronics refers to the use of nanotechnology in electronic components. The term covers a diverse set of devices and materials, with the common characteristic that they are so small that inter-atomic interactions and quantum mechanical properties need to be studied extensively. Some of these candidates include: hybrid molecular/semiconductor electronics, one-dimensional nanotubes/nanowires (e.g. silicon nanowires or carbon nanotubes) or advanced molecular electronics. Nanoelectronic devices have critical dimensions with a size range between 1 nm and 100 nm.

Nanorobots

Nanorobots are so tiny that a billion of billions of such nanorobots would form an object similar in size to a salt grain. They can reach places where no other technical device known to man would fit. Microrobots are the size of a human cell and nano robots are thousand times smaller, the size of a virus. For example, nanorobots can diagnose stomach cancer based on temperature differences. Nanorobots are beginning to be used in deep cleaning of dental root canals. Also significant is the use of magnetic nanorobots in eye surgery. Applying a precise magnetic field rotating the robot, the eye surgeon can define procedure with micrometer precision. Nanorobots then function as a highly precise micro scalpel. It is apparent that they can do a lot more precise and gentle surgery than any conventional scalpel.

Definition
Nanorobots Nanorobots are dynamic systems of molecular machines of a few nanometers in size, the behaviour of which emulates that of living microorganisms – their properties are similar. Unlike living cells, scientists can implement the required functions in nanorobots, e.g. the ability to decompose harmful chemicals in which bacteria would not survive.

A lot of techniques of activating the curing process of medicaments contained in nanorobots is in use already. For example, in photodynamic therapy, a photosensitive substance is injected into the patient's body first and then it is collected on the tumour. Then the affected area is then illuminated with light of a specific wavelength from the outside, activating the substance. Nanorobots are navigated by magnetic field, ultrasound, or light. These are physical phenomena commonly used in medicine. The nanorobot moves thanks to drawing chemical energy from the environment. Having accomplished its mission, it decomposes in the body.

Nanorobots have many times larger surface area, they can carry a lot more medicaments or special chemical tools that can be attached to them. At the same time, however, their development is a lot more complex than that of microrobots, because they are strongly affected by the Brownian motion (random motion of particles suspended in a gas or a liquid) due to their nano dimensions. Each nanorobot is designed differently. Imagine transport vehicles, for example. There is a car for the road, a rocket for space, and a ship for water. Transport vehicles usually have an engine, but there is also a sailboat or a sailplane. And the diversity is similar in nanorobots. The number of variants is basically infinite.

Example
In the US, they already have nanorobots that are swallowed by the patient and then the float through the stomach looking for the tumour and grip on it. Compared to laparoscopy where doctors remove a tissue sample for testing, the nano procedure is a lot less invasive. The nanorobot is programmed to detect the tumour in the stomach based on its temperature that differs from other tissues. The nanorobot then grips on the tumour and holds on to it until pulled out by doctors using a magnet. Tissue is sampled while the wound is minimal.

Repair and improvement of human bodies

Future progress in medicine will lead to extension of human life thanks to corrections of a number of processes that are believed to be responsible for the process of aging. Nanoparticles will also be used to stimulate the natural repair mechanisms of the body. The main focus of this direction is on artificial activation and control of adult stem cells.

Definition
Transhuman Transhuman, or trans-human, is the concept of an intermediary form between human and posthuman. In other words, a transhuman is a being that resembles a human in most respects but who has powers and abilities beyond those of standard humans. These abilities might include improved intelligence, awareness, strength, or durability.

Nanofibrous structures, as mentioned in the previous text, are currently applied in the healing of damaged tissues of the human body, because the nature of the nanofibrous layers is very similar to the nature of the intercellular material. As a result, new cells can successfully grow on the nanofibrous structures. Two-component nanofibers not only improve the quality of treatment, but also significantly improve the effectiveness of treatment. However, nanofibrous structures will not be sufficient for the production of complete, replacement human tissues and even whole organs. For this purpose, precision 3D nano printing appears to be a promising technology. This is a very special technology for 3D printing very fine structures with nanoscale precision.

Another approach to repairing and improving the human body is the use of so-called nanosurgery. Medical applications of nanosurgery could be seen as mere advanced techniques of restoring and maintaining human health, but there is a feasible scenario of creating superhuman abilities (so-called Transhumans). The problems exceed the scope of what is already being discussed in the context of gene therapy, as future surgical procedures could involve implantation of sensors and chips in nano scale that would enhance the existing human abilities.

Example
Scientists have already managed to extend the vision of a mouse into the infrared spectrum using nanosensor implants. It is only a matter of time before humans can see better in the dark. However, first we need to discuss whether enhancing human bodies with features that they naturally do not possess is ethical.

- # Save knowledge

Summary

You reached the end of the content unit about Future use of nanotechnologies in medicine. As there was a lot to learn, here are the most important things you learned about this topic:

Thanks to nanoelectronics, profound changes will soon take place in the healthcare industry, leveraging the traditional strengths of the semiconductor industry - miniaturization and integration. Nanosensors will enable better monitoring of human health and early detection of various diseases.

Nanorobots can reach places where no other technical device known to man would fit. For example, nanorobots can diagnose stomach cancer based on temperature differences. Nanorobots are beginning to be used in deep cleaning of dental root canals. Also significant is the use of magnetic nanorobots in eye surgery. Their use result in less invasive treatment often eliminating the need of surgery and thus anaesthesia.

A lot of techniques of activating the curing process of medicaments contained in nanorobots is in use already. Nanorobots are navigated by magnetic field, ultrasound, or light. The nanorobot moves thanks to drawing chemical energy from the environment. Having accomplished its mission, it decomposes in the body.

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New nanofiber structures allow for better healing of skin and bone wounds. Wounds heal up to tens of percent faster compared to the existing treatment methods; the structure of the filling in damaged bones is a lot more robust, almost identical to that of the original bone, and damaged skin shows a lot less scarring in the end.