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IMPORTANCE OF NANOROBOTICS IN PHARMA AND MEDICAL FIELD

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ABSTRACT

Nanorobotics is the technology of creating machines or robots at or close to the scale of a nanometre (10^{-9} metres), machines constructed at the molecular level (nanomachines) may be used to cure the human body of its various ills. This application of nanotechnology to the field of medicine is commonly called as nanomedicine. Nanotechnology promises futuristic applications such as microscopic robots that assemble other machines or travel inside the body to deliver drugs or do microsurgery. Taking inspiration from the biological motors of living cells, chemists are learning how to utilize protein dynamics to power micro size and nano size machines with catalytic reactions. Nanorobots toolkit contains features like medicine cavity containing medicine, probes, knives and chisels to remove blockages and plaque, microwave emitters and ultrasonic signal generators to destroy cancerous cells, two electrodes generating an electric current, heating the cell up until it dies, powerful lasers could burn away harmful material like arterial plaque. To cure skin diseases, a cream containing nanorobots may be used which remove the right amount of dead skin, remove excess oils, add missing oils, apply the right amounts of natural moisturising compounds, and even achieve the elusive goal of 'deep pore cleaning'. Other fields of applications are to clean the wounds, to break the kidney stones, to treat gout, for parasite removal, for cancer treatment, treatment of arteriosclerosis.

KEYWORDS: Nanoswimmers, Biochips, Nubots, 3D Printing, Oral Hygine, Artificial Blood Restoration, Aging, Arteriosclerosis, Tumor, Diabetes, Gene Therapy.

INTRODUCTION

Nanorobotics is the technology of creating machines or robots at or close to the scale of a nanometre (10-9 metres). More specifically, nanorobotics refers to the still largely theoretical nanotechnology engineering discipline of designing and building nanorobots. Nanorobots (nanobots or nanoids) are typically devices ranging in size from 0.1-10 micrometres and constructed of nanoscale or molecular components. As no artificial non-biological nanorobots have so far been created, they remain a hypothetical concept at this time. Another definition sometimes used is a robot which allows precision interactions with nanoscale objects, or can manipulate with nanoscale resolution. Following this definition even a large apparatus such as an atomic force microscope can be considered a nanorobotic instrument when configured to perform nanomanipulation. Also, macroscale robots or microrobots which can move with nanoscale precision can also be considered nanorobots. Nanobots are robots made of nanomaterials that can carry out tasks. Scientists hope to use nanobots in medicine to kill cancer cells, deliver drugs to target tissues, and improve vaccines. Nanobots are also used in research as DNA probes, cell imaging materials, and cell-specific delivery vehicles.[1]

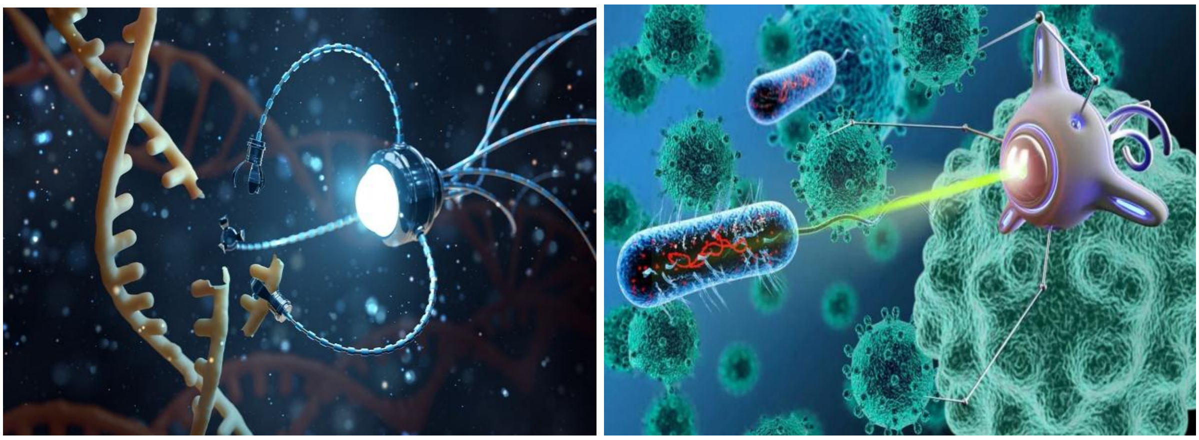

Figure 1: Nanorobots.

TYPES: Smallest engine ever created: "A group of physicists from the University of Mainz in Germany recently built the smallest engine ever created from just a single atom. Like any other engine, it converts heat energy into movement — but it does so on a smaller scale than ever seen before. The atom is trapped in a cone of electromagnetic energy and lasers are used to heat it up and cool it down, which causes the atom to move back and forth in the cone like an engine piston."

3 D-motion nanomachines from DNA: "Mechanical engineers at Ohio State University have designed and constructed complex nanoscale mechanical parts using 'DNA origami' — proving that the same basic design principles that apply to typical full-size machine parts can now also be applied to DNA — and can produce complex, controllable components for future nanorobots.

Nanoswimmer: ETH Zurich and Technion researchers have developed an elastic "nanoswimmer" polypyrrole (Ppy) nanowire about 15 micrometers (millionths of a meter) long and 200 nanometers thick that can move through biological fluid environments at almost 15 micrometers per second. The nanoswimmers could be functionalized to deliver drugs and magnetically controlled to swim through the bloodstream to target cancer cells, for example."

Ant-like nanoengine with 100x force per unit weight: "University of Cambridge researchers have developed a tiny engine capable of a force per unit-weight nearly 100 times higher than any motor or muscle. The new nano-engines could lead to nanorobots small enough to enter living cells to fight disease, the researchers say. Professor Jeremy Baumberg from the Cavendish Laboratory, who led the research, has named the devices 'actuating nanotransducers' (ANTs). 'Like real ants, they produce large forces for their weight'.[2]

Sperm-inspired microrobots: "A team of researchers at the University of Twente (Netherlands) and German University in Cairo (Egypt) has developed sperm-inspired microrobots, which can be controlled by oscillating weak magnetic fields." They will be used in complex micro-manipulation and targeted therapy tasks.

Bacteria-powered robots: "Drexel University engineers have developed a method for using electric fields to help microscopic bacteria-powered robots detect obstacles in their environment and navigate around them. Uses include delivering medication, manipulating stem cells to direct their growth, or building a microstructure, for example."

Nanorockets: "Several groups of researchers have recently constructed a high-speed, remote-controlled nanoscale version of a rocket by combining nanoparticles with biological molecules. The researchers hope to develop the rocket so it can be used in any environment; for example, to deliver drugs to a target area of the body."[3]

MANUFACTURING APPROCHES

Biochips: The joint use of nanoelectronics, photolithography, and new biomaterials provides a possible approach to manufacturing nanorobots for common medical uses, such as surgical instrumentation, diagnosis, and drug delivery. This method for manufacturing on nanotechnology scale is in use in the electronics industry since 2008. So, practical nanorobots should be integrated as nanoelectronics devices, which will allow tele-operation and advanced capabilities for medical instrumentation.

Nubots: A *nucleic acid robot* (nubot) is an organic molecular machine at the nanoscale. DNA structure can provide means to assemble 2D and 3D nanomechanical devices. DNA based machines can be activated using small molecules, proteins and other molecules of DNA. Biological circuit gates based on DNA materials have been engineered as molecular machines to allow *in-vitro* drug delivery for targeted health problems. Such material-based systems would work most closely to smart biomaterial drug system delivery, while not allowing precise *in-vivo* teleoperation of such engineered prototypes.

Surface-bound systems: Several reports have demonstrated the attachment of synthetic molecular motors to surfaces. These primitive nanomachines have been shown to undergo machine-like motions when confined to the surface of a macroscopic material. The surface anchored motors could potentially be used to move and position nanoscale materials on a surface in the manner of a conveyor belt.[4]

Positional nanoassembly: Nanofactory Collaboration, founded by Robert Freitas and Ralph Merkle in 2000 and involving 23 researchers from 10 organizations and 4 countries, focuses on developing a practical research agenda specifically aimed at developing positionally-controlled diamond mechanosynthesis and a diamondoid nanofactory that would have the capability of building diamondoid medical nanorobots.

Biohybrids: The emerging field of bio-hybrid systems combines biological and synthetic structural elements for biomedical or robotic applications. The constituting elements of bio-nanoelectromechanical systems (BioNEMS) are of nanoscale size, for example DNA, proteins or nanostructured mechanical parts. Thiol-ene e-beams resist allow the direct writing of nanoscale features, followed by the functionalization of the natively reactive resist surface with biomolecules. Other approaches use a biodegradable material attached to magnetic particles that allow them to be guided around the body.

Bacteria-based: This approach proposes the use of biological microorganisms, like the bacterium *Escherichia coli* and *Salmonella typhimurium*. Thus the model uses a flagellum for propulsion purposes. Electromagnetic fields normally control the motion of this kind of biological integrated device. Chemists at the University of Nebraska have created a humidity gauge by fusing a bacterium to a silicone computer chip.

Virus-based: Retroviruses can be retrained to attach to cells and replace DNA. They go through a process called reverse transcription to deliver genetic packaging in a vector. Usually, these devices are Pol–Gag genes of the virus for the Capsid and Delivery system. This process is called retroviral gene therapy, having the ability to re-engineer cellular DNA by usage of viral vectors. This approach has appeared in the form of retroviral, adenoviral, and lentiviral gene delivery systems.These gene therapy vectors have been used in cats to send genes into the genetically modified organism (GMO), causing it to display the trait.

3D printing: 3D printing is the process by which a three-dimensional structure is built through the various processes of additive manufacturing. Nanoscale 3D printing involves many of the same process, incorporated at a much smaller scale. To print a structure in the 5-400 µm scale, the precision of the 3D printing machine needs to be improved greatly. A two-step process of 3D printing, using a 3D printing and laser etched plates method was incorporated as an improvement technique. To be more precise at a nanoscale, the 3D printing process uses a laser etching machine, which etches the details needed for the segments of nanorobots into each plate. The plate is then transferred to the 3D printer, which fills the etched regions with the desired nanoparticle. The 3D printing process is repeated until the nanorobot is built from the bottom up. This 3D printing process has many benefits. First, it increases the overall accuracy of the printing process. Second, it has the potential to create functional segments of a nanorobot. The 3D printer uses a liquid resin, which is hardened at precisely the correct spots by a focused laser beam. The focal point of the laser beam is guided through the resin by movable mirrors and leaves behind a hardened line of solid polymer, just a few hundred nanometers wide. This fine resolution enables the creation of intricately structured sculptures as tiny as a grain of sand. This process takes place by using photoactive resins, which are hardened by the laser at an extremely small scale to create the structure. This process is quick by nanoscale 3D printing standards. Ultra-small features can be made with the 3D micro-fabrication technique used in multiphoton photopolymerisation. This approach uses a focused laser to trace the desired 3D object into a block of gel. Due to the nonlinear nature of photo excitation, the gel is cured to a solid only in the places where the laser was focused while the remaining gel is then washed away. Feature sizes of under 100 nm are easily produced, as well as complex structures with moving and interlocked parts.[5]

IMPORTANCE OF NANOROBOTICS IN PHARMA MANUFACTURING FIELD

Nanomedicine: Nanomedicine is the application of nanotechnology to medicine. It is the preservation and improvement of human health, using molecular tools and molecular knowledge of the human body. Present day nanomedicine exploits carefully structured nanoparticles such as nanorobots, dendrimers, carbon fullerenes (buckyballs) and nanoshells to target specific tissues and organs. These nanoparticles may serve as diagnostic and therapeutic antiviral, antitumor or anticancer agents.

Drug delivery and Nubots: Nanotechnology provides a wide range of new technologies for developing customized solutions that optimize the delivery of pharmaceutical products. To be therapeutically effective, drugs need to be protected during their transit to the target action site in the body while maintaining their biological and chemicals properties. Some drugs are highly toxic and can cause harsh side effects and reduced therapeutic effect if they decompose during their delivery. Depending on where the drugs will be absorbed (i.e. colon, small intestine, etc), and whether certain natural defense mechanisms need to be passed through such as the blood brain barrier, the transit time and delivery challenges can be greatly different. Once drug anivies at its destination, it needs to be released at an appropriate rate for it to be effective. If the drug is released too rapidly it might not be completely absorbed, or it might cause gastro-intestinal irritation and other side effects. The drug delivery system must positively impact the rate of absorption, distribution, metabolism, and excretion of the drug or other substances in the body. Nubot is an abbreviation for “nucleic acid robot.” Nubots are organic molecular machines at the nanoscale. Biological circuit gates based on DNA materials have been engineered as molecular machines to allow in-vitro drug delivery for targated health problems. The nubots can perform such challenging and precise tasks as cargo delivery vehicles, imaging probes, cutting the blood supply for cancerous tumors, etc.

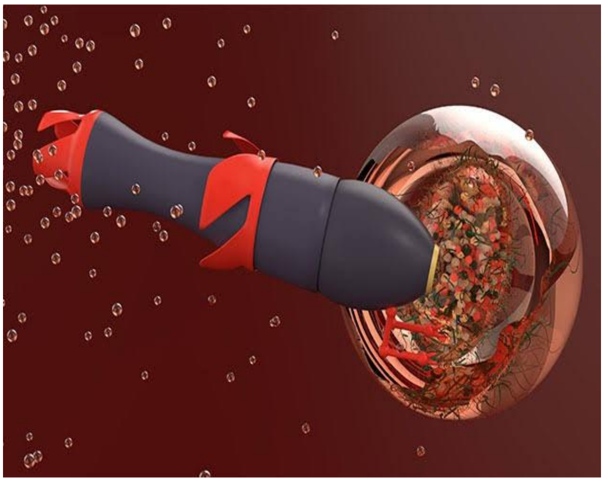

Figure 2: Nubots.

Mouthwash manufacturing

1. Prevention of tooth decay: A mouthwash full of smart nanomachines could identify and destroy pathogenic bacteria while allowing the harmless flora of the mouth to flourish in a healthy ecosystem. Further, the devices would identify particles of food, plaque, or tartar, and lift them from teeth to be rinsed away. Being suspended in liquid and able to swim about, devices would be able to reach surfaces beyond reach of toothbrush bristles or the fibres of floss. Subocclusally dwelling nanorobots delivered by dentifrice patrol all supra-gingival and sub-gingival surfaces metabolizing trapped organic matter performing continues calculus debridement. They prevent tooth decay and provide a continuous barrier to halitosis.

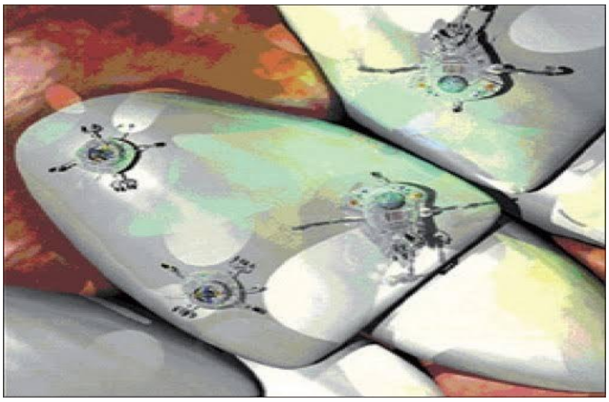

Figure 3: Nanorobotics in Dental Application.

2. Cavity Preparation and Restoration: Multiple nanorobots working on the teeth in unison, invisible to the naked eye, may be used for cavity preparation and restoration of teeth. The cavity preparation is very precisely restricted to the de-mineralized enamel and dentin, thus providing maximum conservation of sound tooth structure.[6]

Figure 4: Cavity Preparation and Restoration.

NANOROBOTS IN MECDICAL TREATMENT FIELD

Artificial Blood and Respiration: Medical nanorobots can be employed as artificial oxygen carriers in the blood, thus assisting and extending normal human respiratory capacities. Hundreds of inhaled nanorobots rushes through a large bronchial junction on their way deeper into the lungs as the patient takes a deep breath.

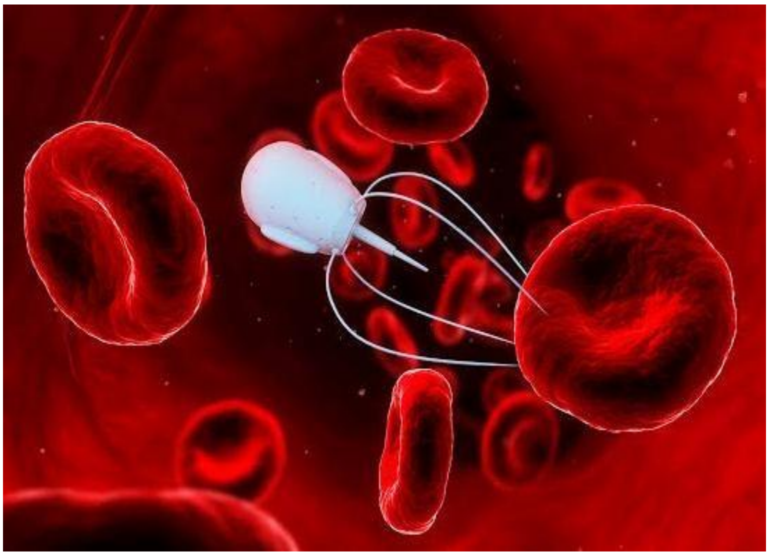

Figure 5: Artificial Blood and Respiration.

Aging: DNA repair machines can repair or replace damaged or miscoded sections of chromosomes. Other medical nanorobots capable of cell repair can purge human tissue cells of unhealthy accumulated detritus and restore these cells to their youthful vigor.

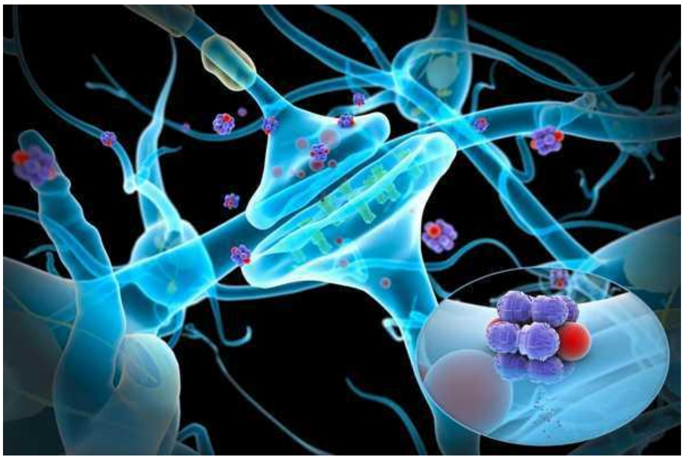

Figure 6: Nanorobots Repairing Damaged Cells.

Treating Arteriosclerosis: This is caused by fatty deposits on the walls of arteries. The device should be able to remove it from theartery walls. Nanorobots could conceivably treat the condition by cutting away the plaque, which would then enter the bloodstream.

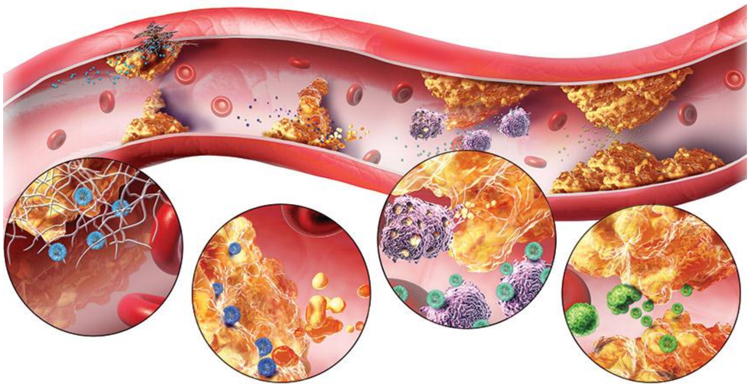

Figure 7: Nanorobots in Arteriosclerosis.

Tumor: Nanorobots with embedded chemical biosensors can be used to perform detection of tumor cells in early stages of development inside the patient's body. The technique is intended to be able to treat tumors that cannot be accessed via conventional surgery, such as deep brain.

Fighting cancer: Doctors hope to use nanorobots to treat cancer patients. The robots could either attack tumors directly using lasers, microwaves or ultrasonic signals or they could be part of a chemotherapy treatment, delivering medication directly to the cancer site. Considering the properties of nano robots to navigate as blood borne devices, they can help on such extremely important aspects of cancer therapy.[7]

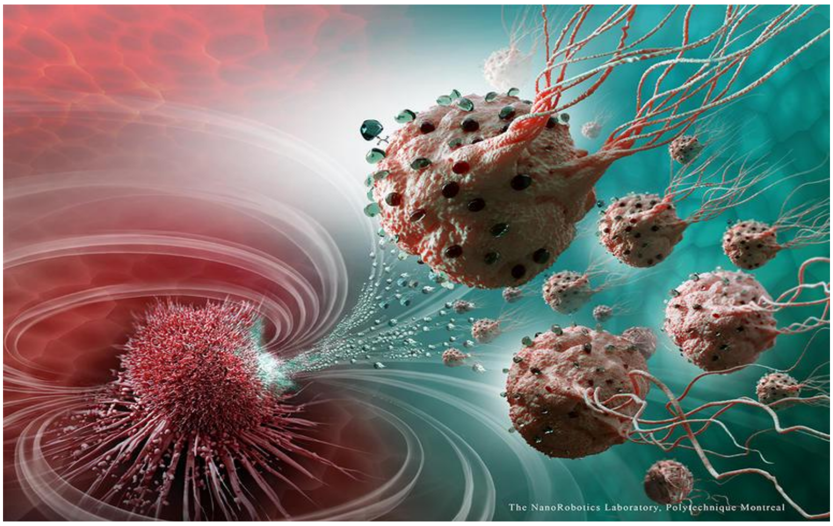

Figure 8: Cancer tumors killed by nanorobots.

Helping the body clot: Nanorobots could travel to a clot and break it up. This application is one of the most complex and sophisticated use sofna norobots**.** One particular kind of nanorobot is the clottocyte, or artificial platelet. The clottocyte carries a small mesh net that dissolves into a sticky membrane upon contact with blood plasma.

Figure 9: Nanorobots Helping the body clot.

Parasite removal: Nanorobots could wage micro-war on bacteria and small parasitic organisms inside a patient. It might takeseveral nanorobots working together to destroy all the parasites.

Cleaning wounds: Nanorobots could help remove debris from wounds, decreasing the likelihood of infection. They would beparticularly useful in cases of puncture wounds, where it might be difficult to treat using more conventional methods.

Breaking up kidney stone: Kidney stones can be intensely painful the larger the stone the more difficult it is to pass. By introducing a micro robot into the urethra in amanner similar to that of inserting a catheter, direct access tothe kidney stones can be obtained, and they can be broken up directly. Nanorobots break up these kidney stones by using small laser and these smaller pieces are passing out in urine outside the body.

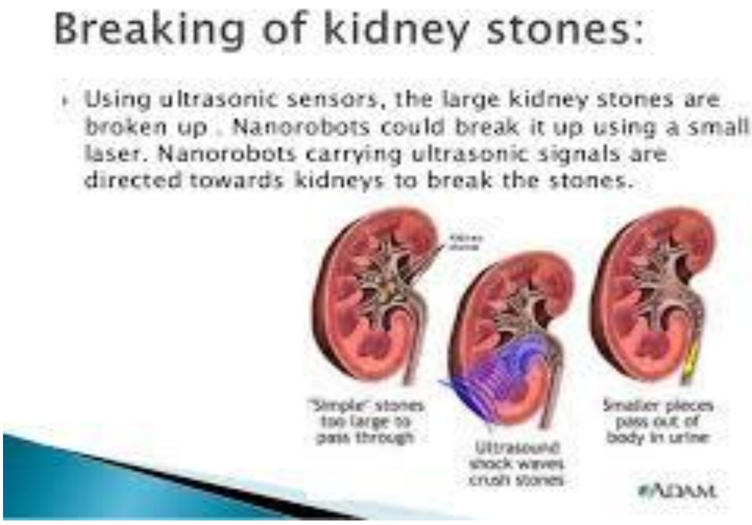

Figure 10: Nanorobots breaking Kidney stones.

Role In Diabetes: Medical nanorobots monitor diabetes by controlling nutrient concentrations in human body including blood glucose levels in diabetic patients. Patients with diabetes must take small blood samples many times a day to control glucose levels. Such procedures are uncomfortable and extremely inconvenient. Serious problems may affect the blood vessels if the correct target levels of glucose in the blood are not controlled appropriately. The level of sugar in the body can be observed via constant glucose monitoring using medical nanorobotics.[8]

Role In Surgery: Surgical nanorobots are introduced into the human body through vascular systems and other cavities. Surgical nanorobots act as semi-autonomous on-site surgeon inside the human body and are programmed or directed by a human surgeon. This programmed surgical nanorobot performs various functions like searching for pathogens, and then diagnosis and correction of lesions by nano-manipulation synchronized by an on-board computer while conserving and contacting with the supervisory surgeon through coded ultrasound signals.

Figure 11: Nanorobotics in gene therapy.

Gene Therapy: Nanorobots are also applicable in treating genetic diseases, by relating the molecular structures of DNA and proteins in the cell. The modifications and irregularities in the DNA and protein sequences are then corrected. The chromosomal replacement therapy is very efficient compared to the cell repair. An assembled repair vessel is inbuilt in the human body to perform the maintenance of genetics by floating inside the nucleus of a cell. Supercoil of DNA when enlarged within its lower pair of robotic arms, the nanomachine pulls the strand which is unwounded for analysis; meanwhile the upper arms detach the proteins from the chain. The information which is stored in the large nanocomputer's database is placed outside the nucleus and compared with the molecular structures of both DNA and proteins that are connected through communication link to cell repair ship. Abnormalities found in the structures are corrected, and the proteins reattached to the Deoxy Nucleic Acid chain once again reforms into their original form.[9]

Acting Against Inflammatory Conditions: An interesting utilization of nanorobots may be their attachment to tramigrating inflammatory cells or white blood cells, to reach inflamed tissues and assist in their healing process. Thus they protect the body against harmful pathogens.

Future footsteps of nanorobotics

(i) In the future, nanorobots could revolutionize medicine. Doctors could treat everything from heart disease to cancer using tiny robots the size of bacteria, a scale much smaller than today's robots.[10]

(ii) Robots might work alone or in teams to eradicate disease and treat other conditions. Some believe that semiautonomous nanorobots are right around the corner doctors would implant robots able to patrol a human's body, reacting to any problems that pop up. Unlike acute treatment, these robots would stay in the patient's body forever.

(iii) Another potential future application of nanorobot technology is to re-engineer our bodies to become resistant to disease, increase our strength or even improve our intelligence.

CONCLUSION

The approach presented in this paper, of combining a precise physical stimulation to establish the environment in which nanorobotics would inhabit,with a nanoronot control design stimulator capable of modeling behavior and used for optimizing performance, has been shown to be of an extreme potential for exploration of technics, strategies and serve as a practical framework for investigating designs and models of medical nanorobots, with an application to the case of establishing a trigger and control criteria for the treatment of stenosed blood vessels having bee successfully demonstrated.

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