THE SCIENCE WORLD
A Monthly e Magazine
ISSN:2583-2212
Oct, 2023; 3(10), 2570-2574

Popular Article

Intelligent micro-/nanorobots as smart vehicles for biomedical therapeutic applications.

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https://doi.org/10.5281/zenodo.10016729

Abstract

Nanorobotics is an emerging science that has attracted tremendous interest among research groups. Nanoscale robotics have the ability to transform multiple energy sources into motion and strength. Micro/nanorobots, are regarded as superior delivery system by altering other forms of energy into propulsion and movements. Furthermore, it can be advantageous as it is directed to targeted sites beneath physiological environments and conditions. They have been validated to possess the capability to encapsulate, transport, and supply therapeutic contents directly to the disease sites, minimizing the dosage of drugs with enhancing efficiency of drugs and less side effects.

Introduction:

Nanotechnology is one of the most emerging and advanced science of today's world. Nanotechnology by definition, the science deals with extremely small structures having size of 1 to 100 nm. As the size increase or decrease, the properties of nanoparticles keep changing enabling various possible way of manipulation for different purposes. It has applications in various fields such as health and medicine, electronics, energy and environment, and also in biological science. This emerging research field has received ever-increasing attentions. One of the first mentions of nanotechnology as a concept emerged in 1867 when James Clerk Maxwell introduced his visionary theory about some submicroscopic entities called Maxwell's Demon, which would have the capacity to handle individual molecules and atoms (Aeran et al., 2015). Later, these tiny machines will be

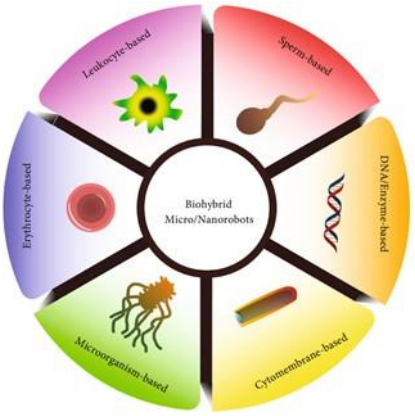

Figure.1. Summary of various biohybrid micro- and nanorobots.

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Published: **18.10.2023**

known as nanorobots. Nanorobotics is one of the most promising domains with many nanotechnological discoveries that deal with the design, assembly, and utilization of molecular devices with nanometer-scale dimensions. Developments in this field with a great impact in medicine. Nanorobots are typically controllable machines made of assemblies of nanometric components which, due to their small size, can interact and even penetrate the cellular membrane, providing a direct pathway to the cellular level. Due to numerous applications of nanorobots in medicine, their development imposes a series of challenges and limitations that derive mainly from various control and behavioral aspects in a dynamic work environment. To avoid the occurrence of rejection reactions from the host immune system, the outside surface of the nanostructures are covered with biomimetic material. Basically, nanorobots are comprise of biological components (e.g., DNA, enzyme, cytomembrane, and cells) and artificial components (e.g., inorganic or polymer particles). They can inherit the parental biological properties, onboard actuation, and sensing capabilities.

Design of Nanorobots

Nanorobots have to travel via narrow channels of only a few hundreds of nanometers in diameter against the body fluids and tissues. Therefore, for effective targeting to diseased sites the design of a nanorobotic propulsion mechanism should take into account the apparently increased viscosity and the low Reynold numbers as the main effects. The principal element used in the manufacture of nanorobot bodies is carbon in the form of diamond/fullerene nanocomposites due to their inert properties and strength for controlled delivery of the payload. For the active locomotion a propulsion tail of nanorobots is required as they sway against the blood flow in the body as shown in figure.2.

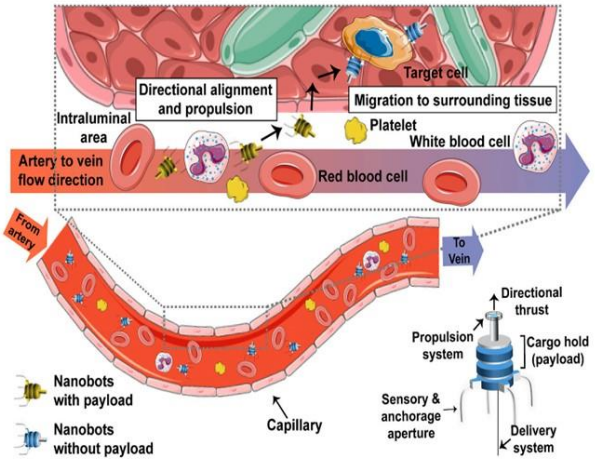

Figure.2. Micro-/nanorobot components for drug delivery: propulsion system, cargo hold of the payload, sensory and anchorage aperture, and delivery system.

Nanorobots for monitoring diabetes

It operates through computational techniques in which nanorobots are designed in such a way that it can sense the glucose levels in the body and provides clinical data in order to suggest patient's diet through 3D prototyping for prevention of diabetes. In vitro studies showed that level of insulin can be regulate in a pulsatile profile as a response to different glucose concentration. A single nanoparticle injection can enables stabilization of the glucose in the blood (<200 mg/dL) for up to 10 days. This platform can be invented for in vivo health monitoring in which the measured data is passed to the patient through mobile phones. If blood glucose level increases it warns the patients through

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alarming in mobile phones in emergency situations.

Nanorobots for kidneys stone disease

Nanorobots are employed for rupturing of kidney calculi through ultrasonic shocks. In this procedure, nanorobots disintegrating the stones in small parts which can easily be passed out during excretion in order to prevent excessive pair.

Nanorobots for Tooth repair

Different nanorobots are functioning simultaneously on dental field include genetic engineering, tissue regeneration and tissue engineering for repair in major tooth issues. The main functions include inducing anesthesia and osseointegration, blocking tooth hypersensitivity by obstructing dentinal tubes, orthodontic treatments by allowing painless tooth uprighting, vertical repositioning and rotating. Similarly, the nanorobots can be used for nanosolutions delivery which contain bonding agent, impression materials, nanofillers, bone replacement materials, for nanoencapsulation of therapeutic agents into polymeric nanocapsules, to form nanocomposites with antibacterial and whitening agents in order to improve polishability and tooth esthetics.

Nanorobots in treatment of gout

Gout is very serious disease in today's modern world mostly suffered in old age group. It is a disorder where the kidney fails to discard waste generated from lysis of fats in the blood. With these techniques it disintegrates the urate crystals at the joints which loses their ability to reverse the condition permanently. For this nanorobots are designed incorporating bone structure then made bone-like nanoparticles. When this particle reached fractured bones site they form a structure which becomes part of bone. The same technology can be applied Arthritis disease as well.

Nanorobots in Opthalmology:

The applications of nanorobots for ophthalmology is to design-sensitive robots to monitor, control, construct, repair, defend, and improve eye function. Employing nanorobots in ophthalmology benefits possibility of injecting them elsewhere in the body and delivering the drug to the target eye area. The other applications include management of oxidative stress, measurement of intraocular pressure, theragnostics, transport drugs for the treatment of choroidal new vessels, assisting in healing processes, and prevention of scar occurrence after glaucoma surgery, treatment of retinal degenerative disease using DNA genes, and ocular prosthetics.

Nanorobots in Gene therapy

With the rapid advancement of nanotechnology, nanorobotic technology is gaining more success not only in genetic engineering but markedly extended to genomics, proteomics, transcriptomics, gene chips, and artificial chromosomes where the nanorobots can be successfully used to detect genetic diseases by comparing the molecular structures of proteins and the DNA of the patient with a data reference. The defects DNA structures and proteins can be corrected or modified

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using the minimally invasive technique of innovative nanorobots. The nanocomponents for nanorobots must be assembled in a functional state to be able to work at the molecular level of patients. The nanomachines used in gene therapy might be assembled fully or partially from DNA structure. For instance, DNA nanorobots is one of new emerging therapeutic tools to promote gene therapy because using DNA to build nanoscale objects is related to the stiffness characteristic and its ability to interact with other intermolecular forces.

Nanorobots in drug delivery

So far, drug delivery by nano/micro machines rely on systemic circulation and the Brownian motion is the main obstacle to their movement in complex body fluids lacking the absence of force and navigation for localised delivery and tissue penetration. To obtain an accurate delivery of medicinal contents to the targeted site of diseases, the drug delivery vehicles are meant to have some distinctive abilities which include navigation, propulsive force, cargo transporting and delivery and tissue perforation. To overcome all these lacuna micro/nanorobots come up with latest solution which satisfy all these necessary characters because micro/nanorobots possess its own motors to deliver the therapeutic loads directly to disease sites thereby decrease the side effects of highly toxic drugs. In addition, an exogenous force such as magnetic field, light energy, and ultrasonic field can be employ as an external power sources to coordinate the behavior of micro/nanomotor drug delivery systems. For an example sperm can be developed as an excellent micro/nanomotor drug delivery system for the treatment of ovarian-related cancers. For that, a micromotor drug delivery system propelled by sperm cells has constructed and assisted by an external magnetic field (Fig.3). This system not only provided propulsion but also acted as the carrier. After internalization of Fe_2O_3 nanoparticles modified by the DOX into sperm cells, the micromotor drug delivery system showed a strong killing effect on human SKOV-3 ovarian cancer cells *in vitro*.

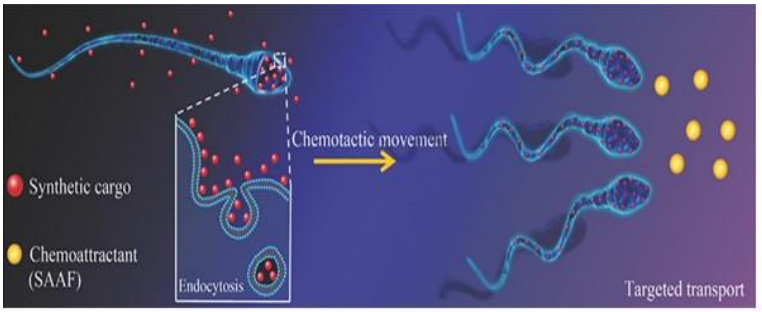

Figure:3. Schematic diagram of the loading and working mechanism of functionalized sperm micromotors. Reproduced with permission. Copyright 2017, John Wiley and Sons.

Conclusions

In today's world, nanorobotics has appeared as an unconventional and adaptable raised area to combine the benefits of micro technologies and robotic skills. Micro/nanorobots acquire unique and multipurpose functions which include rapid mobility in complex biological fluids, bulky cargo-transporting for reversing and extended distances and separation of targets objects. This immense evolution in the field of nano/microrobots from laboratories to a biological system and clinical conversion of micro/nanorobots was a significant step in in vivo researches. Furthermore,

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micro/nanorobots have the capability to detect the health-related issues at just the infancy stage as well.

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