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NANOROBOTICS: FUTURISTIC APPROACH IN MEDICINE

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ABSTRACT: Nano robotics is an emerging, advanced and multidisciplinary field that calls for scientific and technical expertise of medical, pharmaceutical, bio-medical, engineering as well as other applied and basic scientists. Nano robots differ from macro-world robots specifically in their Nano-sized constructs. Due to their small size and wide functional properties, nano robots have created exceptional prospects in medical, biomedical and pharmaceutical applications. Although, no technology is available to construct artificial nano robots, it is now possible to create nano robots by using biological means. Nanorobots, nano machines, and other nano systems are objects with overall dimensions at or below the micro meter range and are made of assemblies of nanoscale components with individual dimensions ranging approximately between 1 to 100 nm. Smaller the size, larger is the specific surface area and energy efficiency. This is the prime concept behind all micro or nanotechnology devices. Even though the nano robots have not yet been deployed in any commercial application with currently available science and technology, the ongoing intensity of research and development work tends to a brighter future where we expect number of miracles with such tiny nano machines. In this context a productive discussion has been carried out concerned with the future application as well as past-present research scenario of nano robotics.

INTRODUCTION: Robotics is the branch of technology that deals with the design, construction, and operation of robots as well as computer systems for their control, sensory feedback, and information processing. This technology is used to develop machines that can substitute for humans and replicate human actions. These automated machines (Robots) take the place of manpower in hazardous manufacturing processes.

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Robotics is being a potential sector for research and industrialization in recent days. Nanotechnology is the design, simulation, control, coordination, and manipulation of nanoscale components ranging between 1-100 nm. A nanometer (nm) is a billionth of a meter. This technology aims to work at the molecular level, atom by atom, to create large structures with the fundamentally new molecular organization.

The concept of modern nanotechnology had given about the advent of smarter and superior materials of nanotechnology, which has left its footprints over several engineering and basic sectors of science. It is a multidisciplinary field requiring advanced level input from different areas of science and technology including physics, chemistry, biology, medicine, pharmaceutical sciences, engineering, biotechnology, and other biomedical sciences [1]. Adriano Cavalcanti is known as a Nano robot pioneer. Cavalcanti is the medical nano robotics inventor for the practical hardware architecture of nanorobots which was integrated as a model based on nano bioelectronics for the application in brain aneurysm, cancer, diabetes, cardiology, and environmental monitoring [2]. Some of the characteristic abilities that are desirable for a nanorobot to function are:

1. Swarm Intelligence – Decentralization and Distributive Intelligence
2. Cooperative behaviour– Emergent and Evolutionary Behaviour
3. Self-assembly and replication – Assemblage at nanoscale and 'Nano maintenance.'
4. Nano Information processing and programmability for programming and controlling nanorobots (autonomous nanorobots)
5. Nano to macro world interface architecture – an architecture enabling instant access to the nano robots and its control and maintenance.

Nanorobots of various shapes and sizes are now capable of inserting medication to the human body's precise organs through veins. Nanorobots are nanoelectromechanical devices (NEMS). Working and manipulating nanorobots is using Scanning Electron Microscopy (SEM) and Atomic Force Microscopy (AFM). Virtual Reality (VR) techniques enhance vision and haptics by a state of 'full immersion or 'telepresence [3]. With the aid of biotechnology, molecular biology (as an engineered organism) and molecular medicine can develop fully self-sufficient nanorobots. Nanorobots are made by using several components such as sensors, actuators, control, power, communication, and by interfacing special cross scales between organic-inorganic systems. Nanorobots can be used in different application areas such as medicine and space technology. Medical Nanorobots are nanodevices used for the purpose of maintaining and protecting the human body against pathogens. Nowadays, nanorobots play a crucial role in the field of Bio-Medicine, particularly for the treatment of cancer, cerebral Aneurysm, removal of kidney stones, elimination of defected parts in the DNA structure, heart attack, anemia. In the pharmaceutical field, it has an immense future as a drug delivery system at an ultrafine level. In this context, a productive discussion has been carried out concerned with the future application and past-present research scenario of nanorobotics and various new approaches of it.

Ideal Characteristics of Nanorobots [4]:

- ✓ Nanorobots must have a size in between 0.5 to 3 microns large with 1-100 nm parts.
- ✓ Nanorobots of larger size than the above will block capillary flow.
- ✓ It will prevent itself from being attacked by the immune system by having a passive, diamond exterior.
- ✓ It will communicate with the doctor by encoding messages to acoustic signals at carrier wave frequencies of 1-100MHz.
- ✓ It might produce multiple copies of it to replace worn-out units, a process called self-replication [4].

Advantages of Nanorobotics [5, 6]:

- Extremely small and lightweight.
- Resources required to produce are plentiful
- Rapid elimination of disease
- They produce copies of themselves to replace worn-out units, a process called self-replication
- Durability
- Cost of surgery is low
- Speed up medical treatment
- Faster and more precious diagnosis
- Harmful day attack is reduced
- Painless treatment
- Automated
- Easily disposable
- They remain operational for years, decades or centuries
- The process is technologically very advanced and reliable.
- The chances of any after-effects or recurrences are completely eliminated.

Types of Nano Robots: Various types of nanorobots that have wide applications in the medical and pharmaceutical fields are mentioned as follows

- Respirocytes
- Clottocytes
- Vasculoids
- Pharmacytes
- Chromallocytes
- Dentifrobots
- Microbivores [7]

Respirocytes (Artificial Mechanical RBC): Artificial mechanical red blood cells are called Respirocytes **Fig. 1**. These blood-borne nanorobots are spherical and have 1 µm diameter. Respirocytes carry oxygen and carbon dioxide molecules throughout the body. Each respirocyte is manufactured with 18 billion atoms, precisely arranged in diamondoid pressure tanks that can store up to 3 billion oxygen and carbon dioxide molecules. Respirocytes would deliver 236 times more oxygen to the body tissues when compared to natural red blood cells [3, 8].

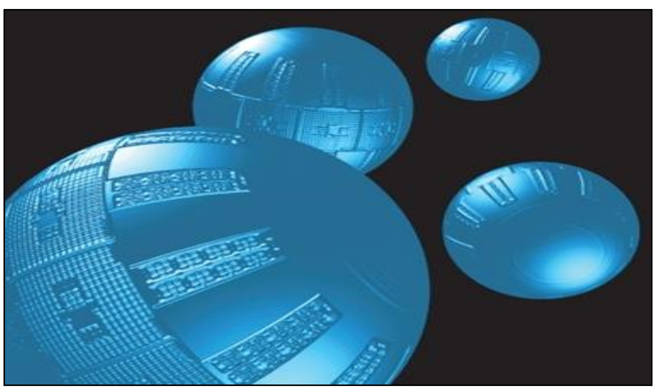

FIG. 1: RESPIROCYTE

Working:

- Each respirocyte consists of 3 types of rotors **Fig. 2**.
- One rotor releases the stored oxygen while traveling through the body.
- The second type of rotor captures all the carbon dioxide in the bloodstream and release it at the lungs.
- The third rotor takes in the glucose from the bloodstream as fuel source [9].

Gas concentration has sensors on the surface of Respirocytes that allow the nanorobot to load and unload the gases. When the respirocyte passes through the lung capillaries, O_2 partial pressure will be high, and CO_2 partial pressure will be low; therefore, the on-board nanocomputer commands the sorting rotors to load in oxygen and release the carbon dioxide molecules. Once the therapeutic purpose is served, the respirocyte may be extracted from circulation, requiring respirocyte activating protocol. During this protocol called nanapheresis, the blood to be cleared would be passed from the patient to a specialized centrifugation apparatus where the ultrasonic transmitters command the respirocyte to maintain neutral buoyancy. There are no other solid blood components that can maintain neutral buoyancy. Hence those components precipitate outwards during centrifugation. The blood components are added back to filtered plasma. The filtered plasma is recombined with centrifuged solid blood components and then returned undamaged to the patient's body. They are used to scavenge carbon monoxide and other poisonous gases from the body.

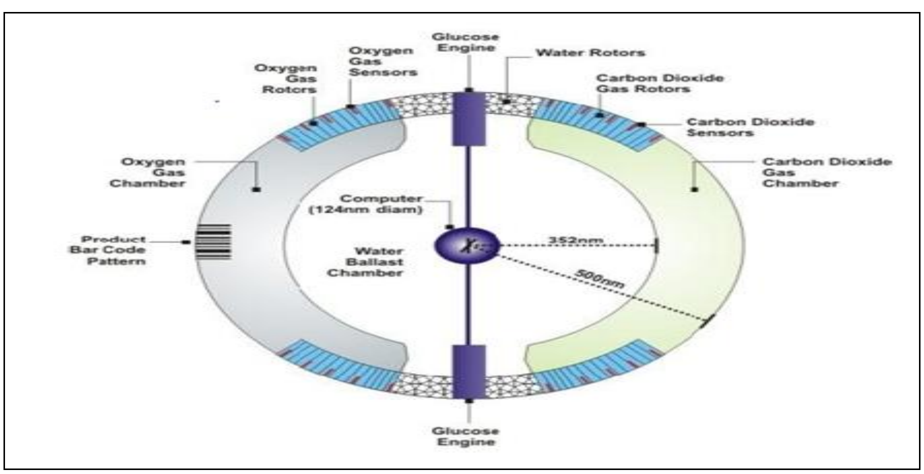

FIG. 2: PARTS OF A RESPIROCYTE

A 5 cc therapeutic dose of 50% respirocyte saline suspension containing 5 trillion nanorobots would exactly replace the gas carrying capacity of the patient's entire 5.4 liters of blood. Respirocytes keep the patient oxygenated for 4hrs following cardiac arrest. Primary medical applications of respirocytes will include transfusable blood substitution, partial treatment for anemia, perinatal neonatal and lung disorders, enhancement of cardiovascular/ neurovascular procedures, tumour therapies, and diagnostics, prevention of asphyxia, artificial breathing, a variety of sports, veterinary, battlefield, *etc*.

Microbivores (Artificial Mechanical WBC): Nanorobotic phagocytes are often termed Micro bivores. A micro bivore is a oblate spheroid device made up of diamond and sapphire, which measures 3.4 µm in diameter along its major axis and 2.0 µm diameter along the minor axis and consists of 610 billion precisely arranged structural atoms.

Micro bivores function as artificial white blood cells. The main function of the micro bivore is to absorb and digest the pathogens in the bloodstream by the process of phagocytosis. These nanorobots are 80 times more efficient as phagocytic agents than marcophages [4].

The microbivore consist of 4 fundamental components:

- An array of reversible binding sites.
- An array of telescoping grapples.
- A morcellation chamber.
- Digestion chamber.

Working: During the process, the target bacterium binds to the micro bivore surface via the species-specific reversible binding site. A collision between the bacterium and the micro bivore brings the surface into intimate contact, allowing the reversible binding site to recognize and weakly bind to the bacterium. A set of 9 different antigenic markers should be specific and confirm the positive binding event confirming the presence target microbe. There would be 20,000 copies of the 9 marker sets distributed in 275 disk-shaped regions across micro bivore. When the bacterium is bound to the binding site, the telescopic robotic grapples rise up from the surface and attach to the trapped bacterium, thereby establishing a secure anchorage. The grapple's handoff motion can transport the bacterium from the binding site to the ingestion port. Further, the bacterium is internalized into the morcellation chamber, wherein the bacterium is minced into nanoscale pieces **Fig. 3**.

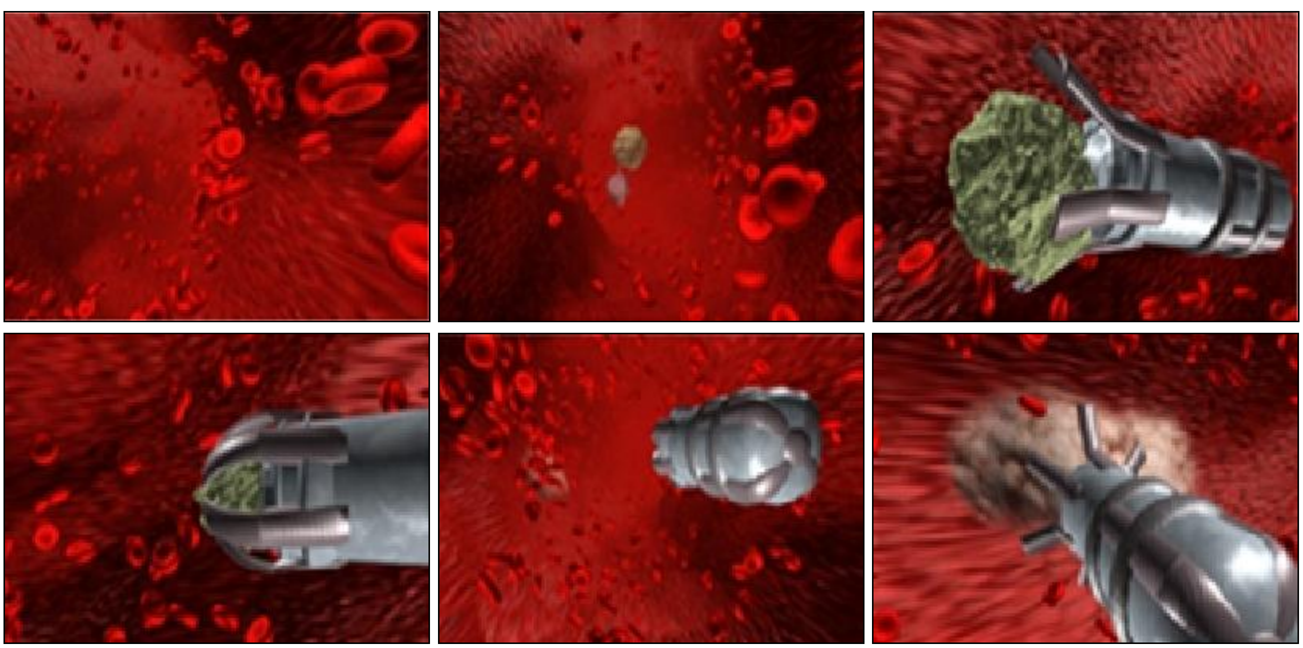

FIG. 3: PROCESS OF PHAGOCYTOSIS BY A NANOROBOTIC PHAGOCYTE

The remains are pistoned into the digestion chamber, which consists of a pre-programmed set of digestive enzymes. These enzymes are injected and extracted 6 times during a single digestion cycle, wherein the morcellate is progressively reduced into amino acids, mononucleotides, free fatty acid and simple sugars **Fig. 4**.

These small molecules are then discharged into the bloodstream through the exhaust port. After the destruction of pathogens, the micro bivores exit the body through the kidneys and are then excreted in urine. The entire cycle of phagocytosis by micro bivore will be completed in 30 seconds. There are no septic shock or sepsis chances as the bacterial components are internalized and digested into non-antigenic biomolecules. The micro bivore is 1000 times faster acting than antibiotic-aided white blood cells, and the pathogen stands no chance of multiple drug resistance. They can also be used to clear respiratory, cerebrospinal bacterial infection or infections in urinary fluids and synovial fluids [8, 9].

FIG. 4: INJECTION BY A NANOROBOT

Clottocytes (Artificial Mechanical Platelets): Clottocyte described as artificial mechanical platelets that would complete hemostasis in approximately 1 sec. It is a spherical nanorobot powered by serum-oxyglucose. It is approximately 2 µm in diameter, containing a fiber mesh that is compactly folded on-board. The fiber mesh would be biodegradable and upon release, a soluble film coating of the mesh would dissolve in contact with the plasma to expose sticky mesh.

Working: As clottocyte-rich blood enters the injured blood vessel, the on-board sensors of clottocyte rapidly detects the change in partial pressure, often indicating that it is bled out of the body. If the first clottocyte is 75 µm away from the air-serum interface, oxygen molecules from the air diffuse through serum at human body temperature. This detection would be broadcasted rapidly to the neighboring clottocytes through acoustic pulses. This allows rapid propagation of a carefully controlled device-enablement cascade. The fiber mesh stick would be blood group-specific to trap blood cells by binding to the antigens present on blood cells.

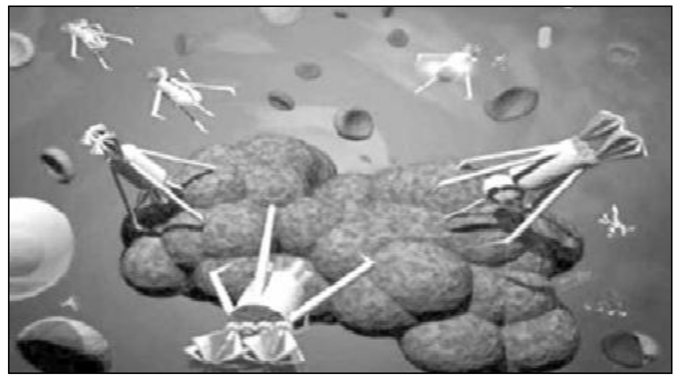

FIG. 5: MECHANISM OF CLOTTING BY A CLOTTOCYTE

Each mesh would overlap on the neighboring mesh and attract the red blood cells to immediately stop bleeding **Fig. 5**. The clotting function by clottocyte is essentially equivalent to that of natural platelets at about 1/10,000th the concentration in the bloodstream, *i.e.,* 20 clottocytes per cubic millimeter of blood. The major risk associated with the clottocytes is that the mechanical platelets' additional activity could trigger the disseminated intravascular coagulation resulting in multiple microthrombi. Clottocytes reduce clotting time and blood loss. In the certain patient's the blood clot is found irregularly due to the usage of nanorobots. We can overcome this problem can by the use of drugs like corticosteroids [8, 10].

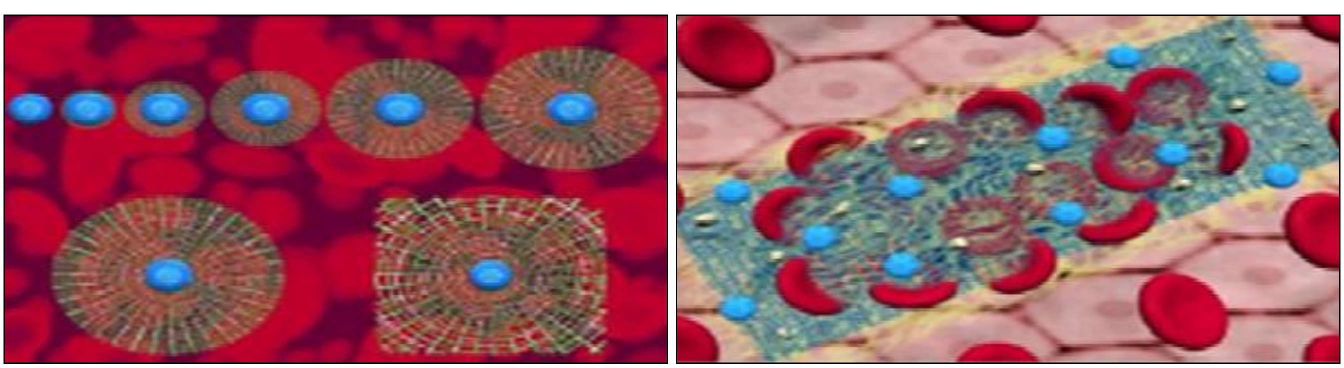

FIG. 6: PHARMACYTES

Pharmacytes: Pharmacytes are the medical nanorobots of size 1-2μm capable of carrying a drug load of 1μm3 in the tanks which are controlled by mechanically shorting pumps. Depending on the requirements, the load is dumped in the extracellular fluid or cytosol using a trans membrane injector system. They are provided with molecular markers or chemotactic sensors that ensure 100% targeting accuracy. The on-board power supply is provided with glucose and oxygen drawn from the local environment, such as blood, intestinal fluid, and cytosol. After the task completion, they can be removed by centrifuge nephrosis or conventional excretory pathways. Pharmacytes can be used to deliver cytocidal agents targeting the cancer cells by cytopenetration or by nano injection. To enhance or upgrade the cell signaling process in the body. It can serve as the source of hormonal replenishment from an external source. Replacement of biochemical agents upon detection by markers and sensors for better cellular capacity [4, 11].

Chromallocytes: These are lozenge-shaped nanorobot that works efficiently as gene delivery system **Fig. 8**. Chromallocytes enter specific cells of the patient and fix what is in need of repair and then harmlessly withdraws from the body. They are used in chromosome replacement therapy (CRT) **Fig. 7** [12].

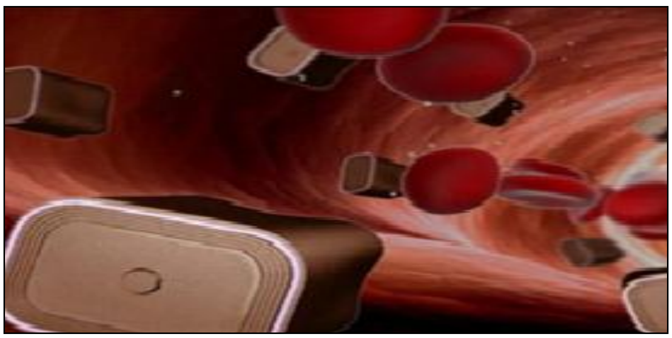

FIG. 7: CHROMALLOCYTES IN BLOOD

FIG. 8: CHROMALLOCYTE

Vasculoids: Vasculoid act as the artificial nanomedical vascular system. It is capable of all functions of the blood, including the circulation of all the respiratory gases, hormones, glucose, cytokines, waste products and cellular components.

The device is extremely complex and has 500 trillion independent cooperating nanorobots [13].

Dentifrobots: These are dental nanorobots. Dentifrobots are mouthwash or dentifrice-containing Nanorobots. These robots are in spider format.

Working: Dental Nanorobots are delivered by mouth wash or toothpaste; they patrol all the supragingival and subgingival surfaces. Dentifrobots break down trapped organic matter into harmless and odourless vapours. They continuously perform calculus debridement. Dentifrobots can be used for preventive/ restorative &curative procedures. Dental nanorobots induce oral analgesia, desensitize teeth, manipulate the tissues to realign and straighten malaligned teeth (orthodontic nanorobots) [14].

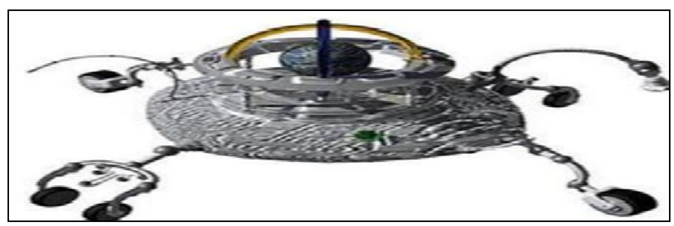

FIG. 9: DENTIFROBOT

Applications of Nano Robots:

Cancer Detection and Treatment: The nano-robots are made with a mixture of polymer and a protein known as transferrin which is capable of detecting tumor cells. The nanorobots would consist of embedded chemical biosensors that can be used in the detection of tumor. The medical nanorobots with chemical biosensors can be programmed to detect different levels of E-cadherin and beta-catenin, aiding in the target identification and drug delivery. The nanorobot could also carry the chemicals employed in chemotherapy to treat cancer at the site. The robots could either attack tumors directly using lasers, microwaves, or ultrasonic signals or as a part of chemotherapy treatment, delivering medication to the cancer site [8, 15, 16, 17].

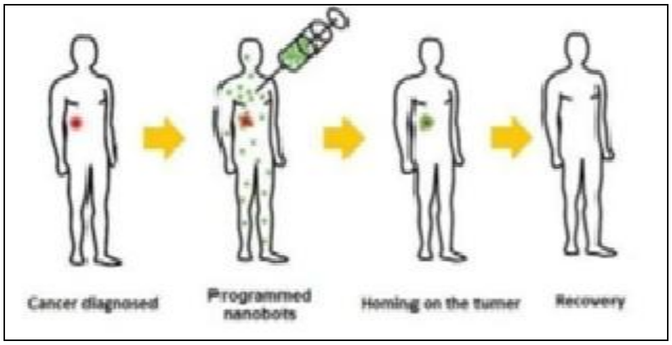

FIG. 10: CANCER TREATMENT

Atherosclerosis: Atherosclerosis is caused by fatty deposits on the walls of arteries. The device should be able to remove these deposits from the artery walls. This will allow for both improving the flexibility of the walls of the arteries and improving the blood flow through them [17].

FIG. 11: ROLE OF NANOROBOT IN ATHEROSCLEROSIS

Drug Delivery: Pharmacytes are the nanorobots designed for the action of drug delivery. The dosage of the drug will be loaded into the payload of the pharmacyte. The pharmacyte will be capable of precise transport and targeted delivery of drug to specific cellular targets. The pharmacytes, upon arriving at the vicinity of the tumor or any target cell would release the drug *via* nano injection or by progressive cytopenetration until the payload delivery is reached [8, 15].

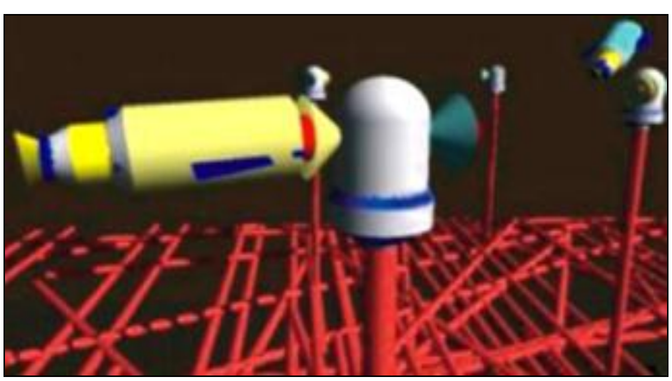

FIG. 12: NANO ROBOTIC DRUG DELIVERY

Role in Diabetes: The glucose molecules are carried through the bloodstream to maintain the human metabolism. The hSGLT3 molecule can define the glucose levels for diabetes patients. The glucose monitoring nanorobot uses the chemosensor, which involves the modulation of hSGLT3 protein gluco-sensor activity. These chemical sensors can effectively determine the need for insulin in the body and inject [8, 15].

FIG. 13: NANOROBOT IN DIABETIC CELL DETECTION

Gout: Gout is a condition where the kidneys lose the ability to remove waste from the breakdown of fats from the bloodstream. This waste sometimes crystallizes at points near joints like the knees and ankles. People who suffer from gout experience intense pain at these joints. A nanorobot could break up the crystalline structures at the joints, providing relief from the symptoms, though it wouldn't be able to reverse the condition permanently [15].

Acting against Inflammatory Conditions: An interesting utilization of nanorobots may be their attachment to transmigrating inflammatory cells or white blood cells to reach inflamed tissues and assist in their healing process. Thus they protect the body against harmful pathogens [15].

In HIV: Nanorobots deliver Anti-HIV drugs to the target site by pharmacytes [15].

Dental Applications: Nanorobots can be used for preventive/restorative &curative procedures.

A. Maintenance of Oral Hygiene: 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 the reach of toothbrush bristles or the fibers of floss. Subocclusally dwelling nanorobots delivered by dentifrice patrol all supragingival and sub-gingival surfaces metabolizing trapped organic matter performing continuous calculus debridement. They prevent tooth decay and provide a continuous barrier to halitosis. As short-lifetime medical nanodevices, they could be built to last only a few minutes in the body before falling apart into materials of the sort found in foods (such as fibre).

B. 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 demineralized enamel and dentin, thus providing maximum conservation of tooth structure.

C. Dentin Hyper Sensitivity: Dentin hypersensitivity is a pathological phenomenon caused by pressure transmitted hydrodynamically to the pulp. Reconstructive dental nanorobots selectively and precisely occlude specific dentinal tubules within minutes, offering patients a quick and permanent cure from hypersensitivity.

D. Esthetic Dentistry: They have been used for dentition re-neutralization procedures in esthetic dentistry. They excavate old amalgam restorations and remanufacture teeth with biological materials indistinguishable from original teeth.

FIG. 14: TOOTH REPOSITIONED BY A NANOROBOT

E. Tooth Repair And Repositioning Nano dental techniques involve genetic engineering, tissue engineering, and tissue regeneration procedures for major tooth repair. Nanorobots provide complete dentition replacement therapy, including both mineral and cellular components. Orthodontic nanorobots can directly manipulate the periodontal tissue, including gingival, periodontal ligament cementum, and alveolar bone allowing rapid and painless tooth straitening rotation and vertical repositioning within minutes [18].

F. Inducing Anesthesia: A colloidal suspension containing millions of active analgesic micron size dental nanorobots will be installed on the patient's gingiva. After contacting the surface of the crown or mucosa, the ambulating nanorobots reach dentin by migrating into the gingival sulcus and pass painlessly through the lamina propria or through 1 to 3 microns thick layer of loose tissue at the Cemento Enamel Junction. Upon reaching the dentin they enter the dentinal tubules up to 1-4 microns depth and proceed towards the pulp guided by a combination of chemical gradient, temperature differentials, and positional navigation under nanocomputer control. Thus the migration of nanorobots from the tooth surface to the pulp occurs in 100 sec. once installed in the pulp, they establish control over nerve impulse, and analgesic nanorobots commanded by the dentist shut down all sensitivity in any particular tooth requiring treatment. When the dentist presses the handheld control, the selected tooth is immediately anesthetized. After the procedure is completed the dentist orders the nano robots to restore all sensation and egress from the tooth.

Nanorobot analgesia offers great patient comfort, reduces anxiety, no needles, greater selectivity, controllability of analgesic effect; fasten completely reversible action; avoidance of side effects and complications [15].

FIG. 15: NANODENTISTRY

Role in Surgery: The surgical programmed nanorobot can act as a semi-autonomous onsite surgeon inside the body. It would perform various functions such as detection of pathology, diagnosing, correcting lesions by nano-manipulation coordinated by an onboard computer. Nanorobots could be soon used for performing microsurgery of the eye as well as surgeries of the retina and surrounding membranes. In addition, instead of injecting directly into the eye, nanorobots could be injected elsewhere in the body, and delivery of the drug can be guided to the eye. Foetal surgery, one of the most risky surgeries today because of the high mortality rate of either the baby or the mother, could soon have a 100% success rate due to the fact that nanorobots can provide better access to the required area inducing minimal trauma. Similarly, other difficult surgeries could also benefit from advances in nanorobotics [15, 16].

Chromosome Replacement Therapy: A typical chromallocyte mission in which all cells in a specific organ inside the human body have their chromosomes replaced with new genetic material. In this procedure, the patient is scanned and prepped while a dose of personalized therapeutic chromallocytes is manufactured.

After infusion into the patient, these mobile cell-repair nanorobots perform limited vascular surface travel into the capillary bed of the targeted tissue or organ.

This is followed by extravasation, his to natation, cytopenetration, and complete chromatin replacement in the nucleus of the target cell, ending with a return to the bloodstream via the same route and subsequent extraction of the devices from the body at the original infusion site [8, 15].

FIG. 16: NANOROBOT IN CHROMOSOME REPLACEMENT THERAPY (CRT)

Artificial Blood and Respiration: Medical nanorobots (Respirocytes) can be employed as artificial oxygen carriers in the blood, thus assisting and extending normal human respiratory capacities. Hundreds of in-haled nanorobots rush through a large bronchial junction on their way deeper into the lungs as the patient takes a deep breath [15].

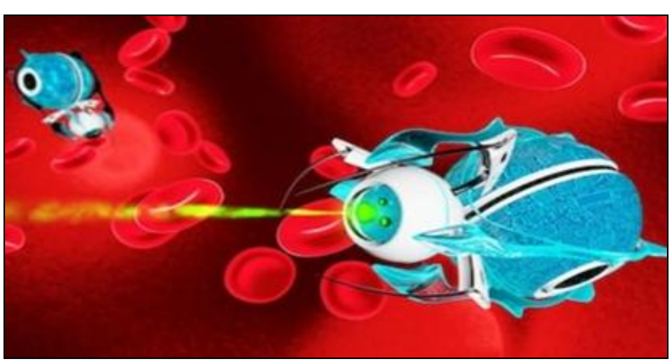

FIG. 17: ARTIFICIAL BLOOD

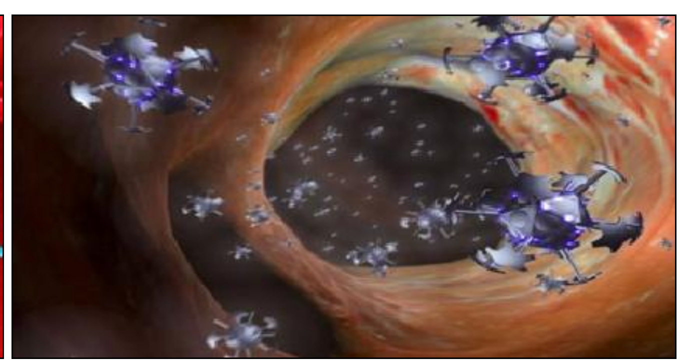

FIG. 18: NANOROBOT IN BRONCHI

Ageing: 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.

Role in Skin Treatments: To cure skin diseases, a cream containing nanorobots may be used. It could remove the right amount of dead skin, remove excess oils, add missing oils, apply the right amounts of natural moisturizing compounds, and even achieve the elusive goal of deep pore cleaning by actually reaching down into pores and cleaning them out. The cream could be a smart material with smooth-on, peel-off convenience [15].

Cleaning Wounds: Nanorobots could help in removing debris from wounds, decreasing the likelihood of infection. They would be particularly useful in cases of puncture wounds, where it might be difficult to treat using more conventional methods [15].

FIG. 19: NANOROBOT IN CLEANING DEBRIS

Helping The Body Clot: The clottocyte carries a small mesh net that dissolves into a sticky membrane upon contact with blood plasma. Clotting could be up to 1,000 times faster than the body's natural clotting mechanism. Doctors could use clottocytes to treat hemophiliacs or patients with serious open wounds [15].

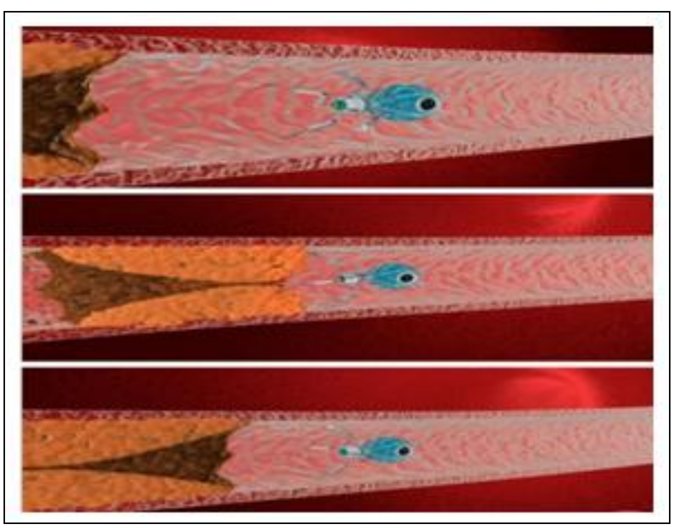

FIG. 20: NANOROBOT IN CLEARING A BODY CLOT

Parasite Removal: Nanorobots could wage micro-war on bacteria and small parasitic organisms inside a patient. It might take several nanorobots working together to destroy all the parasites [15].

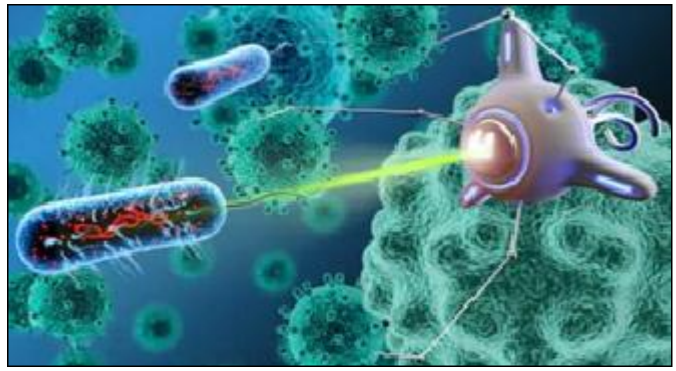

FIG. 21: ROLE IN PARASITE REMOVAL

Role in Reproductive System: Robot technology could be developed in the future to treat disorders such as infertility in new ways. Nanorobot identifies a suitable sperm cell [15].

FIG. 22: NANO ROBOT CARRYING A SUITABLE SPERM

Challenges for Nano Robotics [5, 6]:

- Hard to program
- Sometimes robot goes out of control in the human body
- Limited external control mechanism
- Expensive technology
- Very complicate design
- Should be accurate if not harmful effects occurs (cancer)
- Complicated maintenance
- Hard to interface customize and design
- Very costly for installation purpose
- The technology may take several years to be implemented practically

- The technology may lead to further technological problems like the introduction of artificial reconstruction and artificial intelligence, which will result in the robots going out of control of humans.

CONCLUSION: Nanorobotics is an upcoming futuristic field of science that could have a high prominence in wide functional areas like medical, biomedical, and pharmaceutical fields. The applications and outcomes of nanorobotics have scope in both engineering and medical fields. Hence, this area of research can thus have high prospects in drug development processes and surgical procedures. Future healthcare will make use of sensitive new diagnostics for an improved personal risk assessment. The highest impact can be expected if those major diseases are addressed first, which impose the highest-burden on the aging population: cardiovascular diseases, cancer, musculoskeletal conditions, neurodegenerative and psychiatric diseases, diabetes, and viral infections. Nanomedicine holds the promise to lead to an earlier diagnosis, better therapy, and improved follow-up care, making health care more effective and affordable. Nanomedicine will also allow a more personalized treatment for many diseases, exploiting the in-depth understanding of diseases on a molecular level.

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