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Nanorobots: An Overview

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ABSTRACT

The growing interest in development of newer technologies to improve human health has lead to emergence of a new field called Nanorobotics. Nanorobotics is a technique in which robots of nanometer scale are created. The term nanorobot is a combination of two terms robot and nanometer. The size of nanorobots ranges from 0.5 to 3 microns in diameter. Synonyms of nanorobots are nanobots, nanoids, nanites, nanomachines and nanomites. The main element used in manufacturing of nanorobots will be carbon in the form of diamond/fullerene nanocomposite because of their strength and chemical inertness. Nanorobots may consist of molecular sorting rotors, propellers, sensors and fins. As nanorobots are of nanometer size, they work simillarly to viruses, bacteria, tumor cells and can be used to fight these threats to human body in coming future. The main feature of nanorobots will be its wide applicability in various fields. They can be used in early diagnosis and treatment of cancer and diabetes. In the field of Dentistry nanorobots can be used for oral analgesia, tooth repair, tooth alignment and diagnosis of oral cancer. Better targeted drug delivery can also be achieved in comparison of conventional devices. Other biomedical applications of nanorobots include breakdown of blood clots and kidney stones, in arteriosclerosis, nerve regeneration, parasite removal, as artificial oxygen carrier etc. The review article aims to provide an early glimpse on the structure, design, types, current scenario and future applications of nanorobots in various fields.

Keywords: Nanorobotics, Nanorobot, Nanotechnology

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INTRODUCTION

In the last two decades progress in developing nano size therapeutics and drug delivery system has been remarkable. “Nano” is derived from Greek word which means “dwarf”. Nanotechnology is a process of manipulating matter at atomic level which is measured in nanometers, roughly the size of two to three atoms. It is an extremely diverse and multidisciplinary field ranging from novel extensions of conventional physics to completely new approaches developing new materials and machines with nanoscale dimensions [1].

But all these nanomedicines has few limitations over its advantages like antibiotics can be immunogenic, liposomes may release drug too quickly or entrap it too strongly and are also prone to be captured by reticuloendothelial system (RES). There is potential to design nanosized, bioresponsive system able to diagnose and deliver drugs, in chemotherapy systems able to promote tissue repair and regeneration [2].

To overcome the limitations associated with existing technologies, emergence of a new field called Nanorobotics has taken place. These machines will be highly efficient, controllable, economical, fully operational and will require minimum supervision. This review article shows a glimpse of structure, design, types, applications and current scenario of nanorobots. Preliminary phase of research on nanorobots is going on and commercial applications can’t be promised yet. However, it is clear that the future of Nanorobots is bright.

Structure and design of Nanorobots:

Elements of Nanorobots: - Carbon will likely be the principal element. Many other elements such as Sulphur, Oxygen, Nitrogen, Flourine, Silicon etc. will be used for special purposes in nanoscale gears and other components [3].

Components of Nanorobots [4]:

1. Medicine cavity- It is a hollow cavity inside the nanorobot used to hold small doses of medicine. These nanorobots are capable of transdermal drug delivery even to cancerous cells. As the amount of medicine is very small and drug reaches the targeted site, side effects are also lesser.
2. Probes, Knives and Chisels- These will be used to remove plaque, blockage and breakdown of material. Also they might need a device to crush clots into very small pieces.
3. Microwave emmiters and Ultrasonic signal generators- They will be used by nanorobots for targeting and destroying kidney stones or cancerous cells.

4. Electodes- With the help of electrodes, nanorobots will generate electric current and heat the cells which can be used to kill cancerous cells.
5. Lasers- These lasers could burn the harmful material like arterial plaque, blood clots or cancer cells. These lasers vaporize infected tissues.
6. Microcamera- The nanorobots may contain a microcamera which helps the operator during manual instillment of nanorobot into body.
7. Swimming tail- The nanorobot will require means of propulsion to get into the body as they travel against the flow of blood in the body.

The nanorobots will have motors for movement and manipulator arms for mobility. The two main approaches used for construction of nanorobots are positional assembly and self-assembly. In positional assembly the investigators will put billions of molecules together and let them assemble automatically based on their natural affinities into the desired configuration. In self-assembly the arm of a robot is used to pick the molecules together and assemble manually. Nanorobots have chemical sensors which can detect the target molecules. The nanorobots are provided with swarm intelligence for decentralization activity [4].

Introduction of the device into the body[6]: -

We need to find a way of introducing the nanomachine into the body, and allowing it access to the operations site without causing too much damage. Circulatory system can be a potential route for introduction of nanorobots into the body.

The first is that the size of the nanomachine determines the minimum size of the blood vessel that it can traverse. Though large size of nanorobots offers advantages like versatility and effectiveness, smaller size is preferred to avoid blocking of blood vessels and reduction in blood flow [6].

The second consideration is we have to get it into the body without being too destructive in the nature. This requires that we gain access to a large diameter artery that can be traversed easily to gain access to most areas of the body in minimal time. Femoral artery in the leg is suitable candidate for introduction of nanorobots into body owing to its larger diameter and easy accessibility [6].

Movement of the device[7]:

To detect the problem tissue we need two different types of sensors like long range sensors and short range sensors. Long-range sensors will be used to allow us to navigate to the site of the unwanted tissue. We must be able to locate a tumor, blood clot or deposit of arterial plaque closely enough so that the use of short-range sensors is practical. These would be used during actual operations, to allow the device to distinguish between healthy and unwanted tissue.

Another important use for sensors is to be able to locate the position of the nanorobot in the body. Tracking and controlling nanorobots will require means such as Ultrasound, NMR/MRI, X rays, Radioactive dye, using special chemicals, Tv cameras etc [7].

Advantages of Nanorobots over conventional medical techniques [8]: -

- There are various techniques available to diagnose body ailments as well as to "repair" them but all technologies inevitably have to be phased out sometime. In coming future, nanorobots will aim to overcome the drawbacks of conventional techniques.
- Minimal or no tissue trauma.
- Less post treatment care required
- Continuous monitoring and diagnosis from inside.
- Storage of data and prediction of onset of an ailment.
- Pre-programmed target specific locations.
- Disassemble and get excreted after completion of task.

Types of Nanorobots [9]: -

The types of nanorobots designed by Robert A. Freitas Jr as artificial blood are-

1. Respirocytes
2. Microbivores
3. Clottocytes

Respirocytes [4]:

Respirocytes are the nanorobots designed as mechanical red blood cells having size of 1µm diameter. Respirocytes carry oxygen and carbon dioxide throughout the body and delivers 236 times more oxygen to body tissues when compared to natural red blood cells.

Advantages of Respirocytes [9]: -

Respirocytes do not contain any antigens that determine blood type, so they can be used for all individuals without immunologic reactions.

They provide immediate full capacity oxygen transport in comparison of transfused blood which requires 24 hours to reach full oxygen capacity due to 2,3-di phosphoglycerate depletion.

Respirocytes can be stored for longer period than transfusable blood and can be kept at room temperature.

Mechanism of Respirocytes [4]: -

These respirocytes would contain a tank in which oxygen is held at high pressure, sensors to determine the concentration of oxygen in the bloodstream and valve that releases oxygen when sensors determine that additional oxygen is required. each respirocyte contains three types of rotors. One rotor releases the stored oxygen while travelling through the body. The second type of rotor captures all carbon dioxide in blood stream and release at the lungs. While the third rotor takes in glucose from blood stream as fuel source. There are oxygen rotors in the left, water rotors in the middle and carbon dioxide rotors in right. When the respirocyte passes through the lung capillaries, oxygen partial pressure will be high and carbon dioxide partial pressure will be low. Therefore, oxygen will be loaded and carbon dioxide will be released. The water ballast chambers help in maintaining buoyancy. The respirocytes can also be programmed to remove harmful gases from body. Once the purpose of respirocytes is served, they are removed by the process of nanaphresis.

1. Applications of Respirocytes [11]: -
2. Treatment of anaemia and asphyxia.
3. Useful in maintaining tissue oxygenation during coronary angioplasty, organ transplantation and in cardiopulmonary bypass solutions.
4. Respirocytes could be used as informer devices to map a patient's whole body blood pressure or oxygenation profile.
5. For under water breathing.

Microbivores [4]:

Microbivores are the nanorobots designes as artificial white blood cells or Nanorobotic phagocytes. The microbivore is a spheroid device made up of diamond and sapphire which measures 3.4µm in diameter along its major axis and 2.0 µm diameter along minor axis and consists of 610 billion precisely arranged structural atoms. It traps in the pathogens present in the blood stream and breaks down to smaller molecules.

The microbivore consists of four fundamental components:

An array of reversible binding sites

An array of telescoping grapples

A morcellation chamber

Digestion chamber

Mechanism of action of Microbivores [4]: -

First function of microbivore is to acquire a pathogen for digestion. A collision between a bacterium of the target species and the nanorobotics device brings their surface into intimate contact, allowing reversible binding sites on microbivore hull to recognize and weakly bind to the bacterium. Once the target bacterium has been confirmed and temporarily secured to the microbivore surface at >9 points, telescoping grapples emerge from silos in the nanodevice surface to establish secure anchorage to the microbe's plasma membrane or outer coat. Pathogens are then conveyed towards the morcellation chamber via cyclical ciliary motions. Bacterium is minced into nanoscale pieces in morcellation chamber. Morcellate is pumped from morcellation chamber into digestion chamber where a pre-programmed sequence of engineered enzymes are successively injected and extracted, reducing the morcellate primarily to monoresidue amino acids, mononucleotides, free fatty acids and monosaccharides which are then discharged through exhaust port into the environment. After the destruction of pathogens, the microbivores exist the body through the kidneys and are excreted in urine. The microbivores are 1000 times faster acting than antibiotic aided white blood cells.

- Extended applications of Microbivores [11]: -
- Treatment of infections of meninges and cerebrospinal fluid
- Systemic inflammatory cytokine management
- Biofilm digestion
- Bacterial infection in other fluids and tissues like sputum or in mucous layers of throat
- Viral, fungal and parasitic infections

Clottocytes [4]:

The artificial mechanical blood platelet or Clottocyte may allow complete haemostasis in as little as ~1 second, even in moderately large wounds. This response time is on the order of 100-1000 times faster than the natural system. It is spherical nanorobot powered by serum-oxyglucose approximately 2µm in diameter containing a 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. Blood cells are immediately trapped in the overlapping sticky mesh released by multiple neighbouring activated clottocytes and bleeding halts at once. Clottocytes performs clotting in approx. 1 second while the natural time is 4-5 seconds.

Current scenario of Nanorobots: -

DNA Nanorobots to target cancer cells [12]: - A team of scientists from Israel's Bar-Ilan University started human trials including drug-delivering nanobots in early 2016. The nanorobots are made of the specially folded DNA that serves as a vessel for cancer-treating drugs. Other therapies of cancer damage normal cells but DNA nanorobots attack selectively and precisely on cancerous cells. Only when they encounter a cancerous cell, they open up and release their payload which greatly reduces the damaging effect of the drug on the surrounding tissue. The device is extremely small and only 35 nanometers in width.

The fabricated nanorobot looks like a nanocage similar to an open ended barrel. This molecular barrel has two halves which can open and close. These two halves are connected to each other by molecular hinges and kept close by two molecular locks or latches that are actually made of DNA double halixes. The chemotheraphy drug can be encaged in to the barrel core and secured by molecular anchors inside the nanocage. Drug loading is carried out simply by mixing the nanorobots and the drugs together. Chemotherapy drug simply diffuse in to the inner structure of the nanocage as a result of the mutual attraction between the linker strand and the molecular anchors inside the nanocage [12].

These nanorobots are made by using a technique called DNA origami. In this process, scientists mix small amount of long single stranded, template forming DNA with relatively large amount of pre designed short stranded DNAs which will undergo self-assembly to make an intricate nanoscale structures with desired shapes. DNA latches plays an important role here. The latches open for a specific ligand or a marker. In the absence of the key, the DNA duplexes that function as latches are held sufficiently strong to keep the entire nanocage closed. However, when a specific biomarker is present, specially designed DNA binds with the biomarker key, unzipping the DNA duplex. When both these DNA latches are opened, entire structure will open up delivering the drug.Cancer cells have different cell wall chemistry compared to healthy cells. They have special molecular proteins that are not present in healthy cells. These DNA latches open only when these markers or keys are present. This allows the nanorobot to specifically attack cancerous cells. This is only possible because only those target cells express the correct set of keys that open up the nanocage releasing the toxins. This DNA nanobot cancer treatment system has been developed to identify 12 different types of human cancers including leukemia; a notorious type of cancer involving cancer growth in bone marrow. Clinical trials on humans will be conducted this year [12].

Nanorobots deliver drug into gut tissue of a mouse [13]: -

Researchers working at the University of California, San Diego have designed micro-motor nanorobot that can travel inside a living creature and deliver medicinal payload without any detrimental effects. The nanorobots used in the research were tubular, about 20 micrometers long, 5 micrometers in diameter, and coated in zinc. Once the mouse ingested these tiny tubes and they reached the stomach, the zinc reacted with the hydrochloric acid in the digestive juices to produce bubbles of hydrogen. These gas bubbles help in propulsion of nanorobots. They reached the stomach lining where they embedded themselves, dissolved, and delivered a nanoparticle compound directly into the gut tissue. Nanorobots remained attached to the lining for a full 12 hours after ingestion, thereby proving their effectiveness and robust nature. Further, after the mouse was eventually euthanized and the stomach was dissected and examined for any signs of toxicity. The presence of the nanorobots showed no signs of raised toxicity levels or tissue damage. No announcement has been made regarding further tests or the possibility of human based trials.

Future trends of Nanorobots:

Breaking up blood clots [14]: - Blood clots can cause stroke and also muscle death in the body. So, removal of these clots with the help of nanorobots is essential Nanorobots could travel to a clot and break it up. This application is one of the most dangerous uses for nanorobots – the robot must be able to remove the blockage without losing small pieces in the bloodstream, which could then travel elsewhere in the body and cause more problems. The robot must also be small enough so that it doesn't block the flow of blood itself.

Breaking up kidney stones [14] : - Kidney stones can be intensely painful - the larger the stone the more difficult it is to pass. Doctors break up large kidney stones using ultrasonic frequencies, but it's not always effective. A nanorobot could break up a kidney stones using a small laser and these smaller pieces can pass out in urine from the body.

Nanorobots in Arteriosclerosis [14] : - Arteriosclerosis means plaques developed at the wall of the arteries. Nanorobots could conceivably treat the condition by breaking or cutting away these plaques and then enter in to bloodstream. This application of Nanorobots is important in preventing heart attack.

Nanorobots in Cancer treatment [14] : -

Cancer can be fighted if it get detected in early stage of metastatis. The patient will have more chances for treating from cancer if it diagnosed earlier. Nanorobots with chemical biosensor (nanosensor) are used for detecting the tumours cells in early stage of cancer development. This nanosensor will sense the presence of malignant cells in the body. Nano-carriers used to carry out nanosensor and encapsulated drug to a particular area of cancerous tissues. These encapsulated drugs are delivered by to a Nanorobots particular site. Doctors believe that by delivering small but precise doses of medication to patient, side effects will be minimized withot a loss in effectiveness of medication.

Parasite Removal [14]: - 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.

Nanorobots used in Dentistry [17]: -

Advanced diagnostics - Nanodiagnostic devices can be used for early disease identification at the cellular and molecular levels. Nanodevices might be inserted into the oral cavity for prophylaxis treatment of various diseases [17].

Oral analgesia: - Nanorobots have the ability to induce oral analgesia. To achieve nanoanalgesia, a colloidal suspension containing millions of active analgesic micron size dental robots would be deposited on patient's gingiva by dentist [17].

Tooth repair and durability: - Nanorobots will help in tooth repair and maintaining durability of tooth substance [17].

Tooth alignment:- Nanorobots help in realigning and straightening of irregular set of teeth by directly manipulating periodontal tissues, allowing rapid and painless corrective treatment [17].

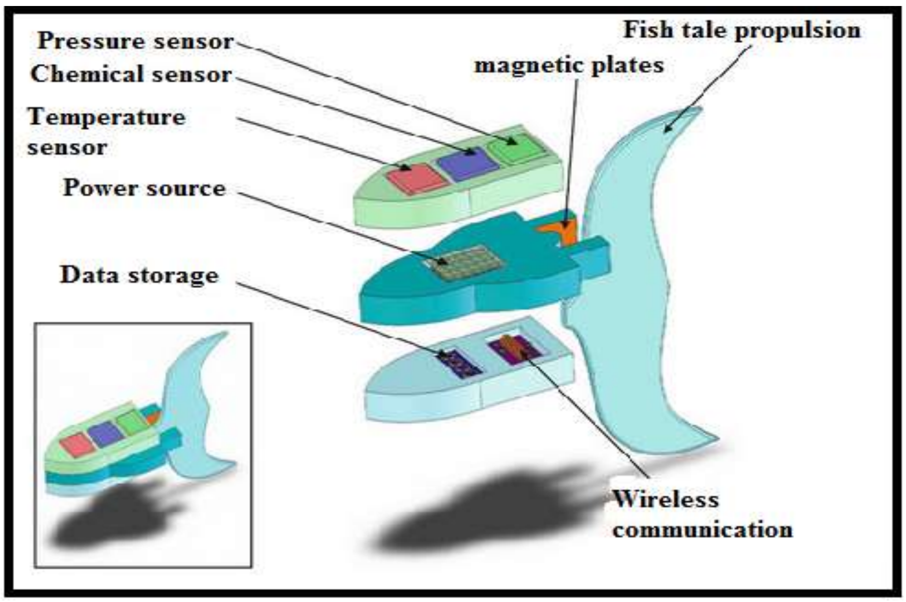

Figure 1: - Components of Nanorobot [5]

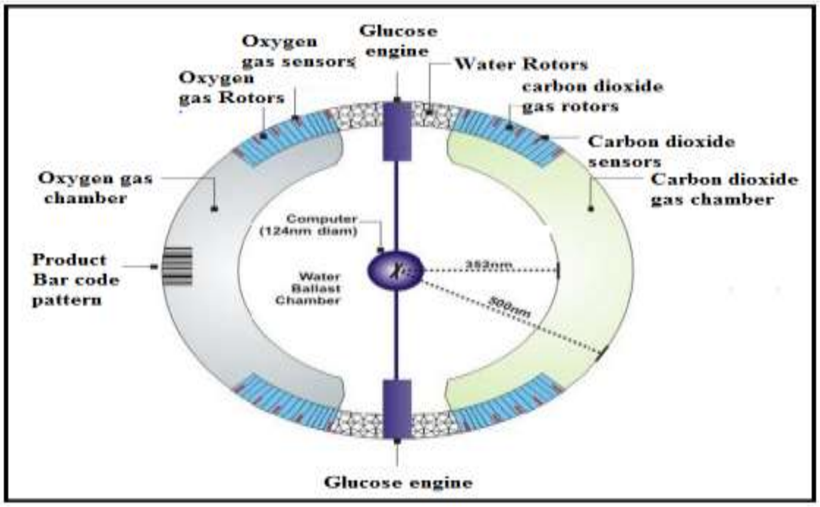

Figure 2: Internal view of Respirocytes[4]

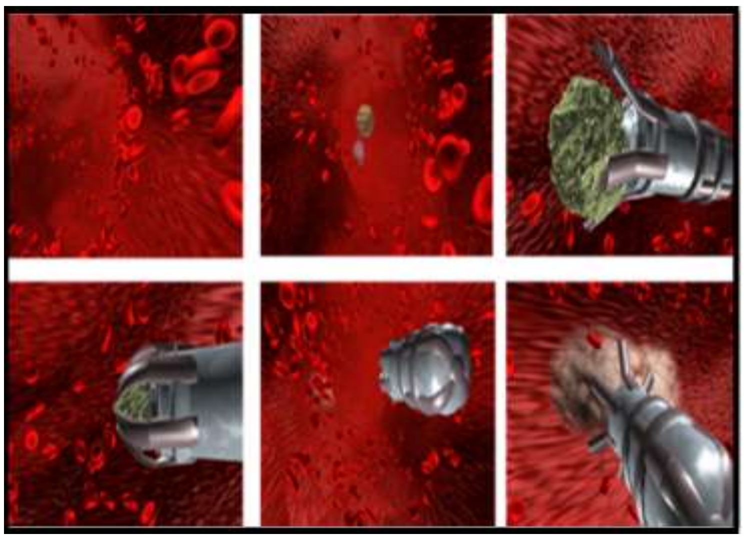

Figure 3: - Mechanism of phagocytosis by Microbivore [4]

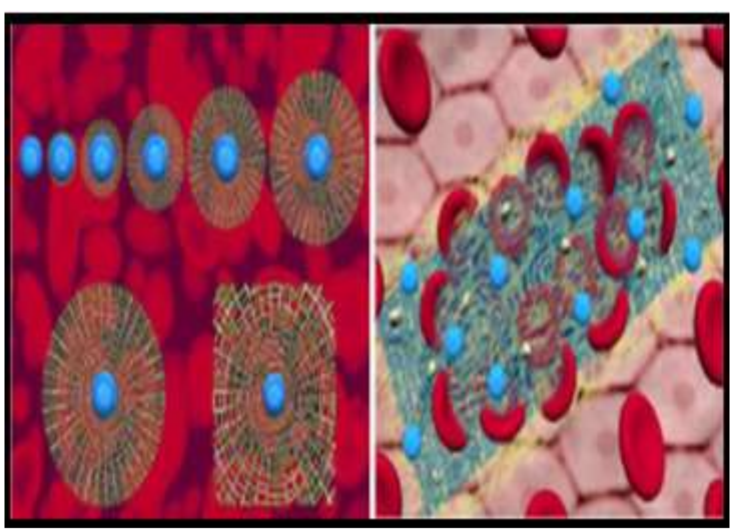

Figure 4: Blood clotting mechanism of Clottocytes [4]

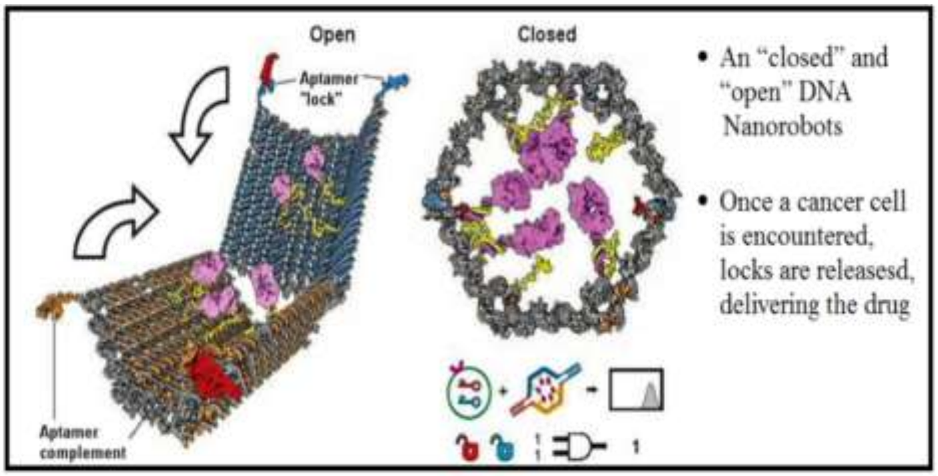

Figure 5: Nanorobots fighting cancer [12]

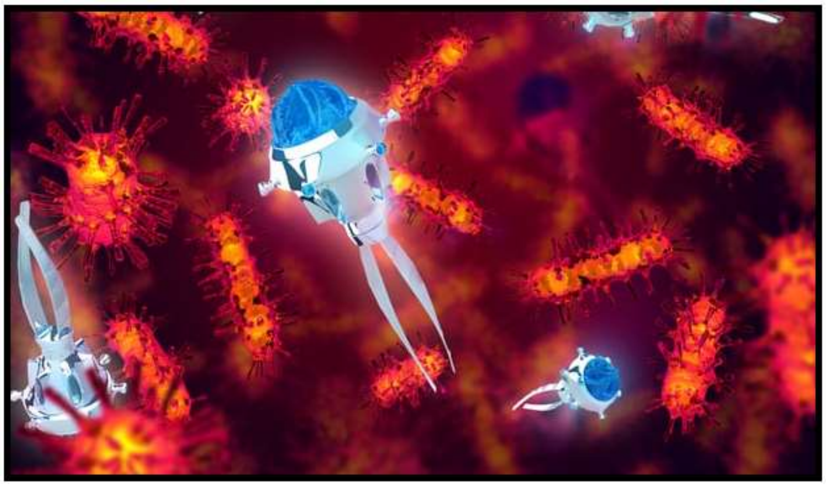

Figure 6: Micro-motor powered nanobots have delivered a nanoparticle compound directly into the gut tissue of a live mouse [13]

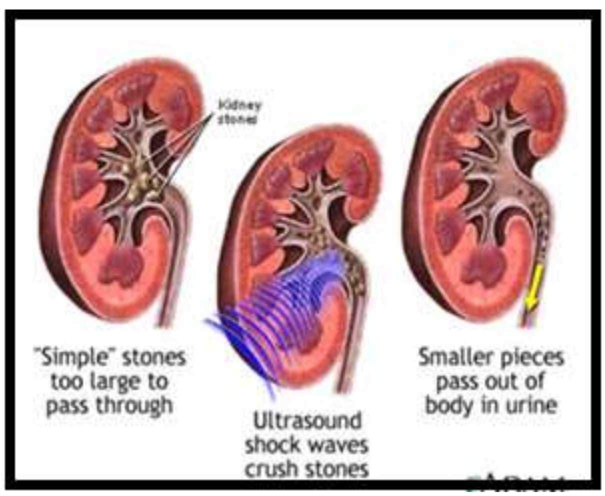

Figure 7: Breaking up kidney stones [14]

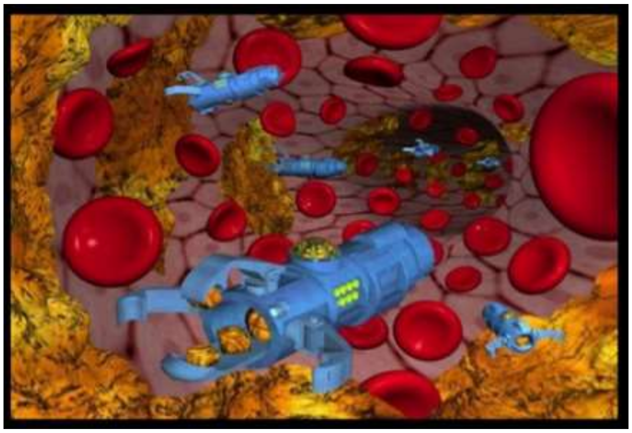

Figure 8: Treating Atherosclerosis [15]

Figure 9: Nanorobots removing parasite from body [16]

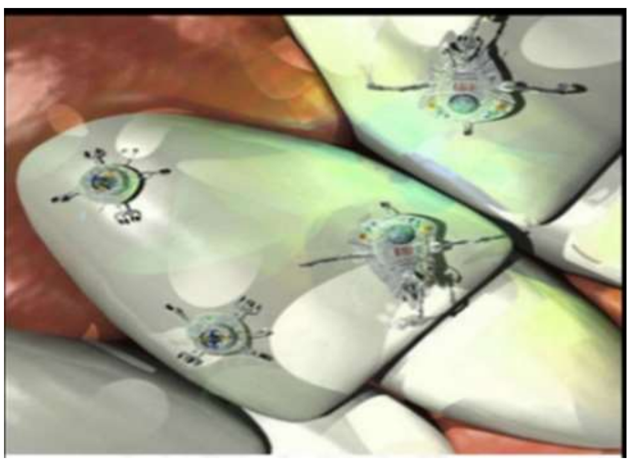

Figure 10: Nanorobots in Dentistry [1]

CONCLUSION:

As can be seen from the above, nanorobots have a promising future in the field of nanotechnology. Over the next couple of years, it is widely anticipated that nanorobotics will continue to evolve and expand in many areas. This hypothesis has to be worked upon to provide personalized treatments with improved efficacy and reduced side effects that are not available today. The effect of these developments in coming future will be so vast that they will probably effect all fields of science and technology.

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