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Nanorobotics: An Impressive Technological Trend

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A B S T R A C T

Nanorobotics is a new and exciting field of nanotechnology that operates at the atomic, molecular, and cellular levels. These tiny robots are made up of carbon and have a toolkit containing useful components such as a medicine cavity for holding medicine, a micro camera, a payload, a capacitor, and a swimming tail. Nanorobots have special sensors that can detect target molecules in the human body, making them useful for diagnosing and treating various diseases such as cancer, diabetes, atherosclerosis, kidney stones, and more. While nanorobots are still being researched, some early molecular models of these medically programmable machines have been tested. This review covers various aspects of nanorobots, including their introduction, history, ideal characteristics, approaches in nanorobotics, basis for development, tool kit recognition, and retrieval from the body, as well as their applications in diagnosis and treatment.

Keywords- Nanorobots, Nanotechnology, Targeted drug delivery system, Nanomedicine, etc.

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INTRODUCTION:-

The demand for targeted drug delivery systems is increasing due to the need for innovative systems to replace difficult procedures. Developing a micro-scale delivery system can replace traditional methods and instruments. Biomedical micro-robots present a potential solution to this and other medical challenges. Nanomedicine provides a promising avenue for treating human diseases and improving biological systems. By engineering nano/micro-scale robots that travel throughout the human body, we can implement new technologies that redefine conventional processes[1].Nanomedicine involves diagnosing, treating, and preventing diseases and injuries, relieving pain, and improving human health using molecular tools and knowledge of the human body as shown in figure No. 1. Nanorobots are "smart" structures capable of actuation, sensing, signaling, information processing, intelligence, manipulation, and swarm behavior at the nanoscale (10-9m) as shown in figure No. 3.

Nanotechnology is an impressive technological trend highlighted by researchers in recent decades. It encompasses the rapid growth of electronics for applications in communication, healthcare (known as nanomedicine), and environmental monitoring. Much research currently focuses on the scientific bottlenecks that reduce the longevity of living organisms, especially humans. Among these bottlenecks are diseases that have little or no alternative treatment and healing.DDS (Drug Delivery System) is an alternative diagnostic and/or treatment that has been displayed in the academic community[2]. An interdisciplinary approach that combines the skills of various professionals in medicine, pharmaceuticals, chemistry, and physics can facilitate research on nanomedicine or studies on DDS and nanorobotics [3]. The demand for targeted drug delivery systems is growing, and developing a micro-scale delivery system can replace traditional methods and instruments. Biomedical micro-robots are one possible solution to this and various other medical challenges. By engineering nano/micro-scale robots that travel throughout the human body, we can implement new technologies that redefine conventional processes.

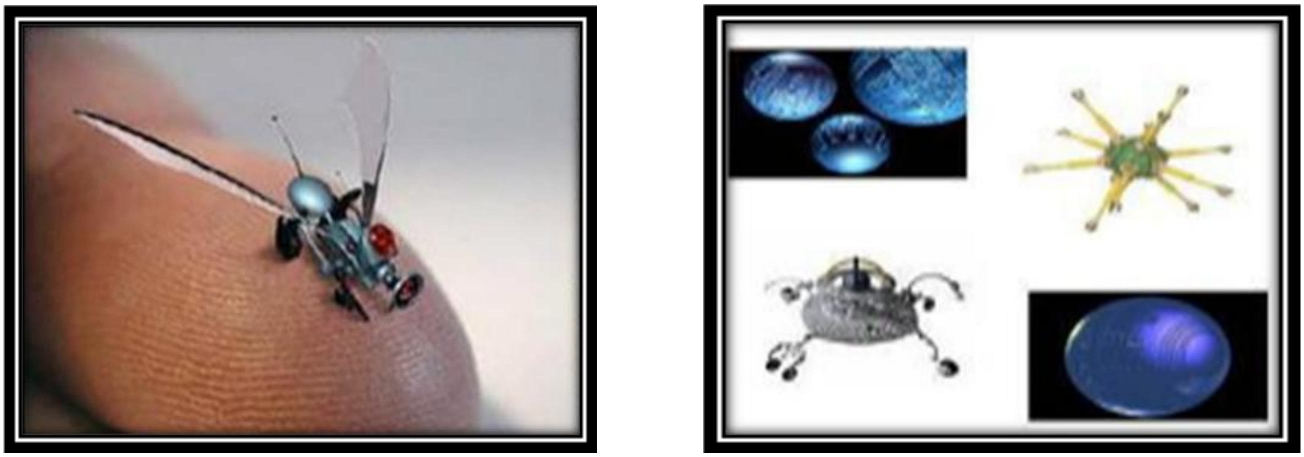


Figure 1: Nanorobots

History of Nanorobots:-

In the 1980s, Nobel Prize laureate Richard Smalley extended his vision to carbon nanotubes, discovered by Sumio Iijima, which he envisions as the next super interconnection for ultra-small electronics. The term nanotechnology has evolved to mean the manipulation of elements to create unique and useful structures [4].

- December 29, 1959: Richard Feynman gives the famous “There’s Plenty of Room at the Bottom” talk, which marks the first use of the concepts of nanotechnology. He describes how individual atoms and molecules can be manipulated.
- 1974: Professor Norio Taniguchi defines nanotechnology as “the processing of, separation, consolidation, and deformation of materials by atom/molecule”.
- 1980s: Dr. Eric Drexler publishes several scientific articles promoting nanoscale phenomena and devices.
- 1986: The book Engines of Creation: The Coming Era of Nanotechnology by Dr. Eric Drexler is published. He envisions nanorobots as self-replicating. This is the first book on nanotechnology.

Beginnings:-

- 1981: Gerd Binnig and Heinrich Rohrer of IBM Zürich invent the Scanning Tunneling Microscope (STM). This is used for imaging surfaces at the atomic level and identifying some properties, such as energy.
- 1985: Discovery of fullerenes (molecules composed entirely of carbon) with many applications in materials science, electronics, and nanotechnology.
- 1991: Discovery of Carbon nanotubes (cylindrical fullerenes) as a direct result of the fullerenes. They exhibit high tensile strength, unique electrical properties, and efficient thermal conductivity. Their electrical properties make them ideal for circuit components (i.e. transistors and ultracapacitors). Recently, researchers in chemical and biomedical engineering have used carbon nanotubes as a vessel for delivering drugs into the body[5].

Content:-

- 1991: Invention of atomic force microscope (AFM). This is one of the foremost tools for imaging, measuring, and manipulating matter at the nanoscale. It performs its functions by feeling the surface with a mechanical probe. Since it allows for precision interaction with materials on the nanoscale, it is considered a nanorobot.
- 2000: The United States National Nanotechnology Initiative is founded to coordinate federal research and development in nanotechnology. This marks the start of a serious effort in nanotechnology research.
- 2000: The Company Nanofactory Collaboration is founded. It develops a research agenda for building a nanofactory capable of building nanorobots for medical purposes.
- Currently, DNA machines (nucleic acid robots) are being developed. They perform mechanical-like movements, such as switching, in response to certain stimuli.
- Molecular-sized robots and machines paved the way for nanotechnology by creating smaller and smaller machines and robots.

Ideal Characteristics:-

1. To communicate with doctors, the nanorobot will encode messages into acoustic signals with carrier wave frequencies between 1 and 100 MHz
2. The nanorobot is designed to self-replicate, producing multiple copies to replace worn-out units.
3. After completing its task, it can be retrieved by allowing it to be excreted through the usual human channels, or it can be removed by active scavenger systems.
4. To be effective, nanorobots should have a size between 0.5 and 3 microns, with parts that are 1-100 nm in size.
5. In order to prevent the immune system from attacking the nanorobot, it will have a passive diamond exterior [9].

Advantages of Nanorobot:-

1. Nanotechnology allows us to manipulate matter at the atomic and molecular levels to create functional materials, devices, and systems with novel properties and phenomena.
2. The benefits of nanotechnology are numerous, including its environmentally friendly nature
3. Minimal pollution during production
4. No waste of materials
5. Greater durability and faster completion of tasks compared to larger robots.
6. Moreover, nanorobots can self-replicate and operate only at specific sites, without generating any harmful activities or side effects.

Disadvantages:-

1. The cost of designing nanorobots is very high, making it a complicated process [10].
2. Electrical systems can generate stray fields that may activate bioelectric-based molecular recognition systems in biology.
3. Electrical nanorobots are vulnerable to electrical interference from external sources such as RF or electric fields, EMP pulses, and stray fields from other in vivo electrical devices.
4. It is hard to interface, customize, and design such complex devices.
5. Nanorobots can pose a severe risk in the field of terrorism, as they can be utilized as a new form of torture by terrorist and anti-groups.
6. Nanotechnology has the capability of destructing the human body at the molecular level.
7. Privacy is also a significant concern with nanorobots.
8. As they are designed to be compact and minute, there are chances for more eavesdropping than already exists.
9. The nanorobot must be very accurate; otherwise, harmful effects may occur.

Composition of Nanorobots:-

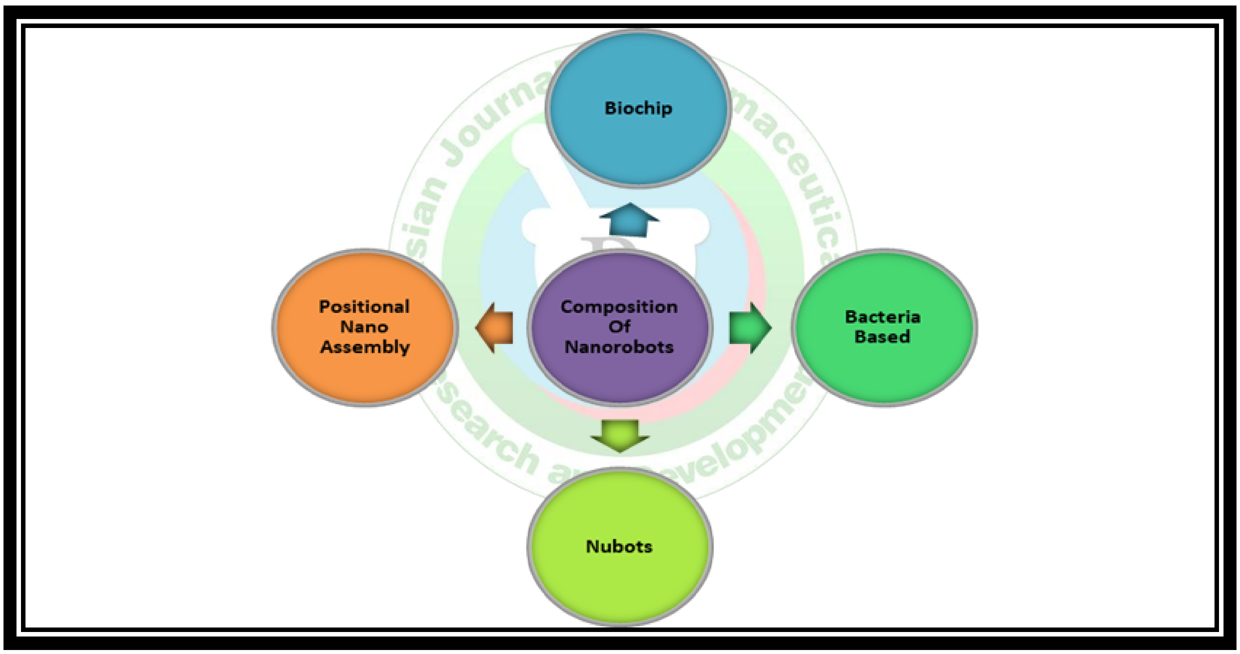


Figure 2: Composition of Nanorobots

Biochip:-

Synthesis combines nanoelectronics, photolithography, and biomaterials to manufacture nanorobots for surgical instrumentation, diagnosis, and drug delivery. Biochips are used in electronics manufacturing. By integrating nanorobots with biochips, medical instrumentation and teleportation can be enhanced [6, 7].

Bacteria-Based:-

This approach uses Escherichia coli bacteria with a flagellum for propulsion and electromagnetic field control [8].

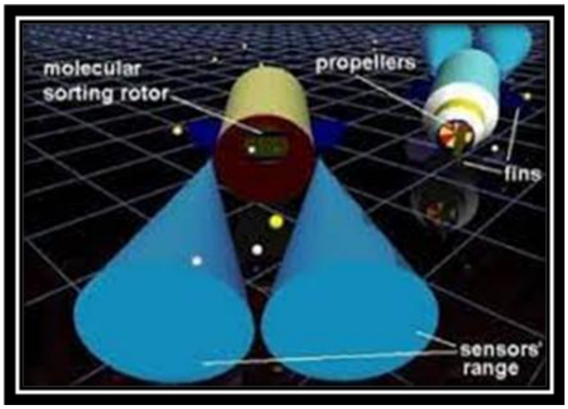
Positional Nano Assembly:-

Robert Freitas and Ralph Merkle developed a research agenda for controlled diamond mechanical synthesis and robots.

Nubots:-

Nubots are nanoscale nucleic acid robots. Various DNA walkers have been reported by research groups including NYU, Caltech, Duke University, Purdue, and the University of Oxford [8].

Structure of Nanorobot:-



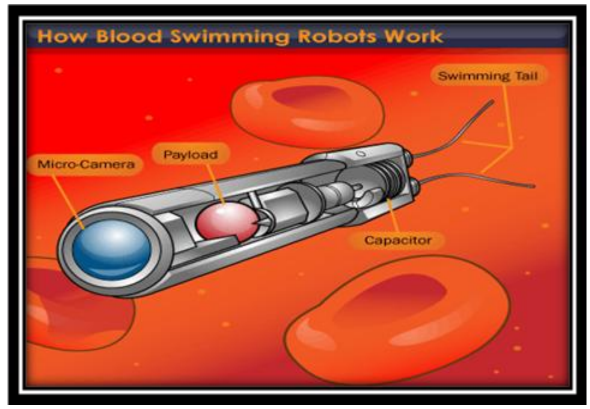


Figure 3: Structure of Nanorobots

Types of Nanorobots:-

Respirocytes:-

Artificial erythrocytes, also known as red blood cells, are approximately 1μm in diameter. Respirocytes are spherical Nano-medical devices designed by Freitas RA that operate as artificial mechanical red blood cells. These devices are diamondoid 1000-atmosphere pressure vessels with active pumping powered by endogenous serum glucose. They can deliver 236 times more oxygen to the tissues per unit volume than natural red blood cells while simultaneously managing carbonic acidity. Red blood cells carry oxygen and carbon dioxide molecules throughout the body. Respirocytes exchange gases via molecular rotors and consist of three types of rotors. One rotor releases the stored oxygen, the second rotor captures all the carbon dioxide molecules in the bloodstream and releases them to the lungs, and the third rotor takes in glucose from the bloodstream as a fuel source.

Microbivores:-

Also known as artificial white blood cells or nanorobotics phagocytes are approximately 3.4 μm in diameter. They trap pathogens present in the bloodstream, break them down into smaller molecules, and digest them into the bloodstream. The function of microbivores is called phagocytosis, and an entire cycle of phagocytosis is completed in 30 seconds. Microbivores are 1000 times faster acting than antibiotic-aided WBCs, so they can be used in bacterial infections.

Clottocytes:-

Also known as artificial mechanical platelets are approximately 2 μm in size. The natural blood clotting process takes 2-5 minutes to complete. In some patients, blood clots occur irregularly, which can be treated with corticosteroids. However, these drugs have side effects. To avoid side effects, choanocyte nanorobots can be used instead of drugs. They can complete hemostasis in just 1 second. The response time of choanocytes is 100-1000 times faster than the natural hemostatic system

Applications:-

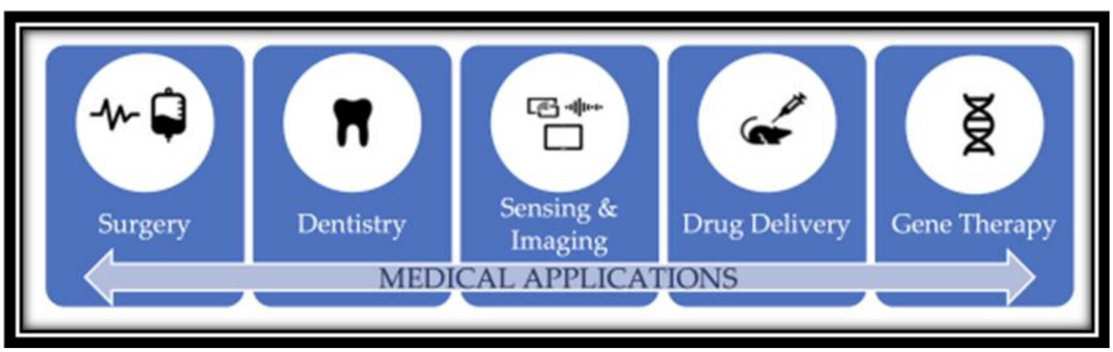


Figure 4: Medical Applications of Nanorobots.

In Cancer Detection and Treatment:-

Successful treatment of cancer heavily relies on the timely detection of the disease, ideally before metastasis occurs. Medical technologies and therapy tools currently available can help treat cancer effectively, but the chances of survival increase substantially if the disease is detected early on[11]. To further improve the treatment process, it is important to develop targeted drug delivery systems that can minimize the side effects of chemotherapy. One such system involves the use of nanorobots with folate materials attached to their surface. These materials help attract the nanorobots to the cancerous cells, which are known as folate-receptor cells as shown in figure No. 5. The folate material is modeled as an object attached to the nanorobot for better visualization of the treatment process. Nanorobots have the ability to navigate through the bloodstream and can be used to detect tumor cells in the early stages of development within the patient's body[12]. Integrated nanosensors can be used to detect the intensity of E-cadherin signals, which can aid in the early detection of cancer. A hardware architecture based on nano-bioelectronics can be utilized for the application of nanorobots for cancer therapy [13]. The proposed model has been analyzed in real-time to obtain conclusive results.

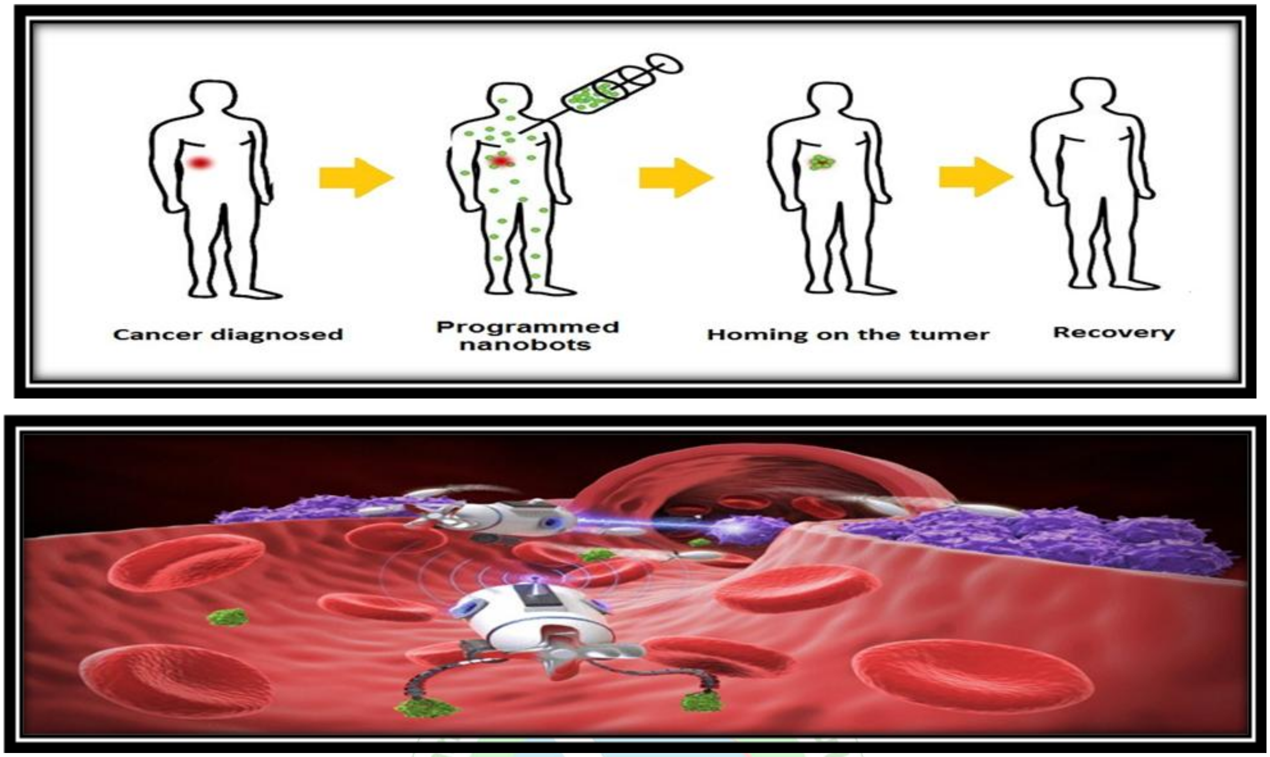


Figure 5: Advances Of Medical Nanorobots For Future Cancer Treatments

In Arteriosclerosis:-

To target plaque build-up in the body, doctors inject microscopic particles through the femoral artery in the leg. They use a long-range sensor, like radioactive dye, to guide the particles directly to the site of the plaque. Once the plaque has been located, a rotating needle and diamond-chipped burr are used to grind it into tiny particles as shown in figure No. 6.

Figure 6: Treating Atherosclerosis In Future

In Surgery:-

Surgical Nanorobots have the potential to be introduced into the human body through the vascular system or at the ends of catheters into different vessels and cavities [14]. These specially designed robots can act as a semiautonomous surgeon inside the human body, performing various functions such as searching for pathology, diagnosing and correcting lesions through nanomanipulation as shown in figure No. 7. The robot can be programmed or guided by a human surgeon, and coordinated by an on board computer while maintaining contact with the supervising surgeon via coded ultrasound signals [15].

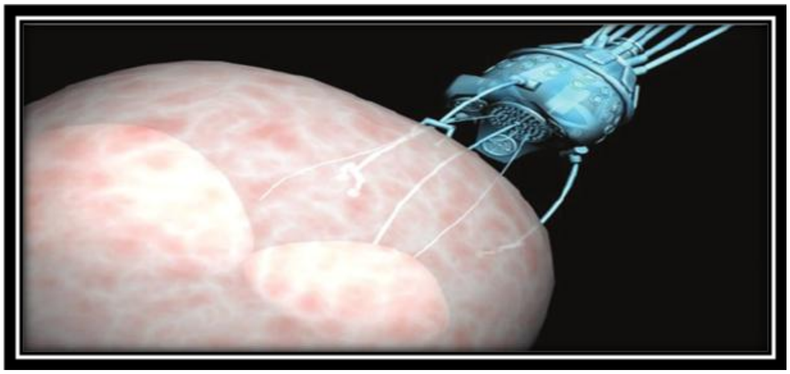


Figure 7: Nanorobots using Surgery

Nanorobots in Gene Therapy:-

Medical nanorobots can treat genetic diseases effectively by comparing the molecular structures of DNA and proteins in cells to known reference structures. Any irregularities found in either structure can be corrected, or desired modifications can be made. In some cases, chromosomal replacement therapy is more efficient than cytorepair. A repair vessel built by an assembler floats inside the nucleus of a human cell and performs genetic maintenance as shown in figure No.4. The nanomachine uses its lower pair of robot arms to stretch a supercoil of DNA and gently pulls the unwound strand through an opening in its prow for analysis. Meanwhile, the upper arms detach regulatory proteins from the chain and place them in an intake port [16]. With a diameter of only 50 nanometers, the repair vessel is smaller than most bacteria and viruses, yet capable of providing therapies and cures beyond the reach of present-day physicians. With trillions of these machines coursing through a patient's bloodstream, diseases such as cancer, viral infections, and arteriosclerosis could be eradicated.

In the Diagnosis and Treatment of Diabetes:-

Glucose level maintenance is crucial for healthy metabolism and diabetes treatment. HSGLT3 protein helps regulate extracellular glucose concentration, and it acts as a sensor to identify glucose [17]. A nanorobot prototype model with embedded CMOS nanobioelectronics detects glucose levels, modulating hSGLT3 protein glucosensor activity [18]. Significant data can be transferred via RF signals to the patient's mobile phone. If glucose levels reach critical levels, the nanorobot emits an alarm [19]. The simulator workspace shows a venule blood vessel with nanorobots and red blood cells [20].

In Kidney Stones:-

Kidney stones can be intensely painful the larger the stone the more difficult it is to pass. A nanorobot could break up kidney stones using a small laser as shown in figure No.8.

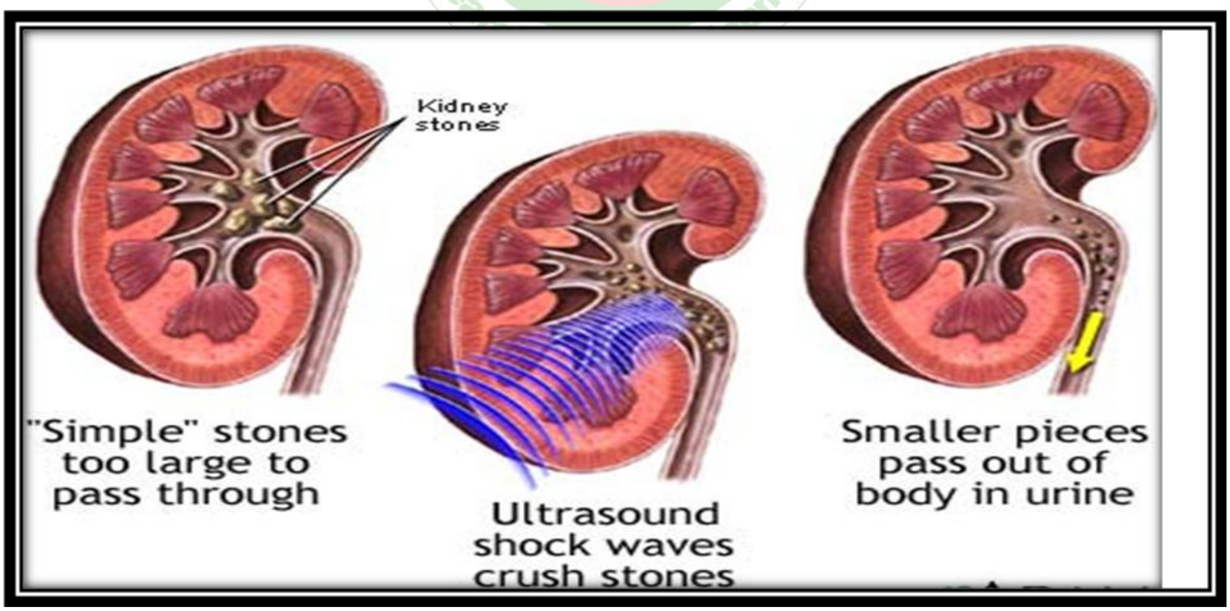


Figure 8: Nanorobots Cure Kidney Stones

Nanorobotic Dentifrices:-

(Dentifrobots) Nanorobotic dentifrices, when delivered through mouthwash or toothpaste, have the ability to cover all subgingival surfaces. They can then break down trapped organic matter into harmless and odorless vapors. When properly configured, dentifrobots can detect and eliminate pathogenic bacteria present in the plaque and other areas as shown in figure No. 9&10. These tiny devices are purely mechanical and can safely deactivate themselves when swallowed, making them safe for use.

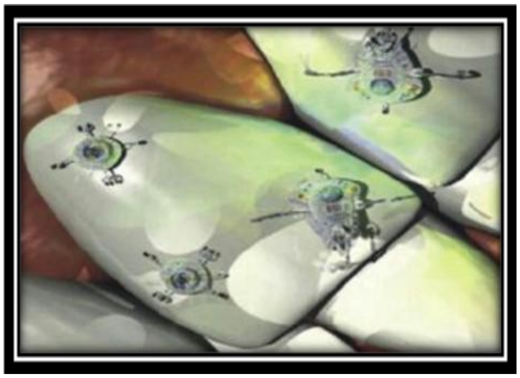


Figure 9: Nanodentifrice

Figure 10: Nanorobots in Tooth Repair

CONCLUSION:-

Nanorobotics, with all its challenges and opportunities, is poised to become an integral part of our future. It has the potential to provide personalized treatments with improved efficacy and reduced side effects. Research and development of nanorobots for common applications in fields such as medicine and defense technology should pave the way for a safer and healthier future. When considering the severe side effects of existing therapies, nanorobots are found to be more innovative and supportive in the treatment and diagnosis of lethal diseases. They can serve as diagnostic and treatment tools for patients with cancer and diabetes. Researchers are working tirelessly to optimize products based on this technology for better therapy and improved outcomes. Nanomedicine is slowly but surely ushering in the new industrial revolution.

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