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A Brief Review on Nanorobotics

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Abstract: The nanorobotics is the technology of the creating machines or the robots at or close to a scale of the 10-9metres[nanometre] nanorobots.Nanorobots have the capacity to precisely release drugs in the body for targeted delivery.Nanobots have great potential within the pharmaceutical industry to optimize drug delivery. Due to their small size, nanobots can enter and cross difficult-to-reach regions of the body, such as the blood-brain barrier. These nanorobot are made of nano materials and these have holds great potential in drug delivery through passive or active targeting mechanisms throughout the last few decades.

One of the benefits of using nanorobots is that they can be equipped with sensors that detect changes in their environment, which means that drugs can be released exactly when and where they are needed.The field of nanorobotics has witnessed considerable advancements, capturing the attention of pharmaceutical researchers and drug delivery scientists. Nanorobots, constructed from nanomaterials, play a vital role in administering drugs with precision, enhancing efficacy, and minimizing the risk of unwanted side effects.

This classification sets the stage for exploring various applications, including cancer therapy, surgery, regenerative medicine, cell therapy, gene therapy, and broader biomedical applications. Despite significant progress, several concerns and challenges must be addressed before incorporating nanorobots into routine patient care.This articles focuses on nanorobots, ,composition of nanorobots, mechanism of nanorobots & applications of nanorobots.

Keyword: Nanorobots, mechanism, composition and applications

I. INTRODUCTION

Nanorobotics in drug delivery is an innovative field that harnesses the potential of nanotechnology to revolutionize how medications are administered within the human body. These nanoscale devices, often referred to as nanorobots or nanobots, hold great promise for enhancing the precision and efficiency of drug delivery. This technology involves the design and manipulation of nanoscale structures, typically ranging from 1 to 100 nanometers, to perform specific tasks, such as targeted drug delivery.[1]

One of the primary advantages of using nanorobotics in drug delivery is the ability to target specific cells or tissues with a high degree of precision. Traditional drug delivery methods often result in systemic distribution of medications, affecting both healthy and diseased tissues. Nanorobots, on the other hand, can be engineered to navigate through the bloodstream and deliver drugs directly to the site of action.

This targeted approach minimizes side effects and enhances the therapeutic efficacy of the drugs[2,3].

Nanotechnology involves the intricate process of designing, fabricating, and manipulating materials at the nanoscale [1]. The examination of robots at the nanoscale is termed nanorobotics, an integral facet of the broader field known as nanotechnology. Nanorobots exhibit capabilities such as sensing, actuating, signaling, processing information, demonstrating intelligence, and displaying swarm behavior at the nanoscale [2].

These devices consist of various components tailored to execute specific tasks, with the components being constructed at the nanoscale (ranging from 1 to 100 nanometers) [3,4]. Nanobots, also known as nanorobots, nanites, nanoids, nanomachines, or nano-mites, represent a burgeoning focus in contemporary research [1,4]. The term "nanobot" is a fusion of "nano," signifying very small or minute, and "bot," denoting a programmable device or robot [1]. The applications of nanorobots in the medical field are diverse, encompassing areas such as cancer treatment [5,6], surgery, precision medicine [7], diabetes monitoring, dentistry, blood monitoring, and drug delivery [1,4,5].

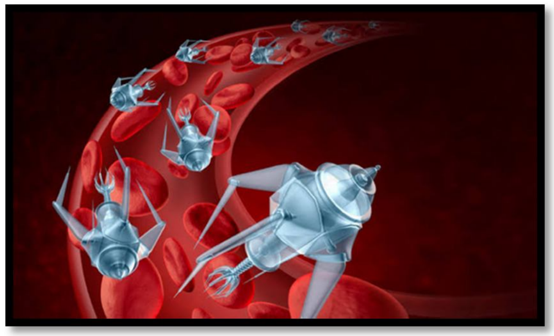

Figure1: Nanorobot

II. NANOROBOTICS IN DRUG DELIVERY

Nanorobotics in drug delivery is an innovative and promising field that leverages the principles of nanotechnology and robotics to revolutionize the way medications are administered. These nanoscale robotic devices, often referred to as nanorobots or nanobots, hold great potential for enhancing precision, targeting specific cells or tissues, and minimizing side effects associated with traditional drug delivery methods.[6,7]

Key Components of Nanorobotics in Drug Delivery:

1) *Nanomaterials*
- Nanorobots are typically constructed using various nanomaterials such as nanoparticles, nanotubes, and nanocomposites.
- These materials possess unique properties at the nanoscale, including high surface area, reactivity, and the ability to interact with biological entities.[5]

2) *Design and Functionality*
- Nanorobots are designed with careful consideration of technological advancements, morphology, functional aspects, and power supply.
- They are equipped with functionalities that enable self-navigation, precise targeting, and controlled drug release.[6]

3) *Drug Encapsulation and Delivery*
- Nanorobots can encapsulate drugs within their structure, protecting them from degradation until they reach the target site.
- Controlled drug release mechanisms allow for the delivery of therapeutic agents with precision, ensuring maximum efficacy.[9]

4) *Targeted Drug Delivery*
- One of the primary advantages of nanorobotics in drug delivery is the ability to target specific cells or tissues.
- Nanorobots can be designed to recognize specific biomarkers associated with diseases, enabling precise delivery of drugs to affected areas[10].

A. *Advantages of Nanorobots[8-12]*
1) Augmentation of Bioavailability: The nanorobot drug delivery system significantly improves bioavailability.
2) Access to Inaccessible Anatomical Areas: Nanorobots can reach anatomical locations that are beyond the reach of conventional surgical procedures.
3) Targeted Drug Payloads: Nanorobots efficiently transport drug payloads and precisely release drug molecules at specific locations.
4) External Control and Precision: Nanorobots are operable externally through computer control, utilizing knobs for precise modulation of drug release amounts, dosing frequency, and release timing.

B. Disadvantages of Nanorobots.[13-15]

1) High Design, Component, and Construction Costs: The design, components, and construction of nanorobots incur considerable expenses.
2) Complexity of Technology: The technology employed for nanorobot design is intricate and highly sophisticated.
3) Vulnerability to Electrical Interference: Nanorobots, relying on electric components, are susceptible to external electrical interference, such as RF or electric fields, EMP pulses, and stray fields from other in vivo electrical devices.
4) Impact on Biological Systems: Electrical systems may generate stray fields that activate bioelectric-based molecular recognition systems in biology, potentially causing severe adverse effects at the cellular level.

III. COMPOSITION OF NANOROBOTS

The composition of nanorobots varies based on their design and intended applications. Some common components and approaches include:

A. Biochip Integration

1) Involves combining photolithography, nano electronics, and biomaterials.
2) Enables manufacturing for medical applications like drug delivery, surgical instrumentation, and diagnosis.
3) Integration with biochips in nano electronics devices for tele-operation and advanced medical capabilities.

B. Bacteria-Based Design

1) Utilizes biological microorganisms, such as Escherichia coli.
2) Propulsion often involves the flagellum of bacteria.
3) Motion control achieved through the application of electromagnetic fields.

C. Positional Nano Assembly

1) Precise arrangement of nanoscale components using methods like manipulating individual atoms or molecules.
2) Provides meticulous control over nanorobot structure and function.
3) Crucial for enhancing efficiency in medical applications, especially in drug delivery systems.

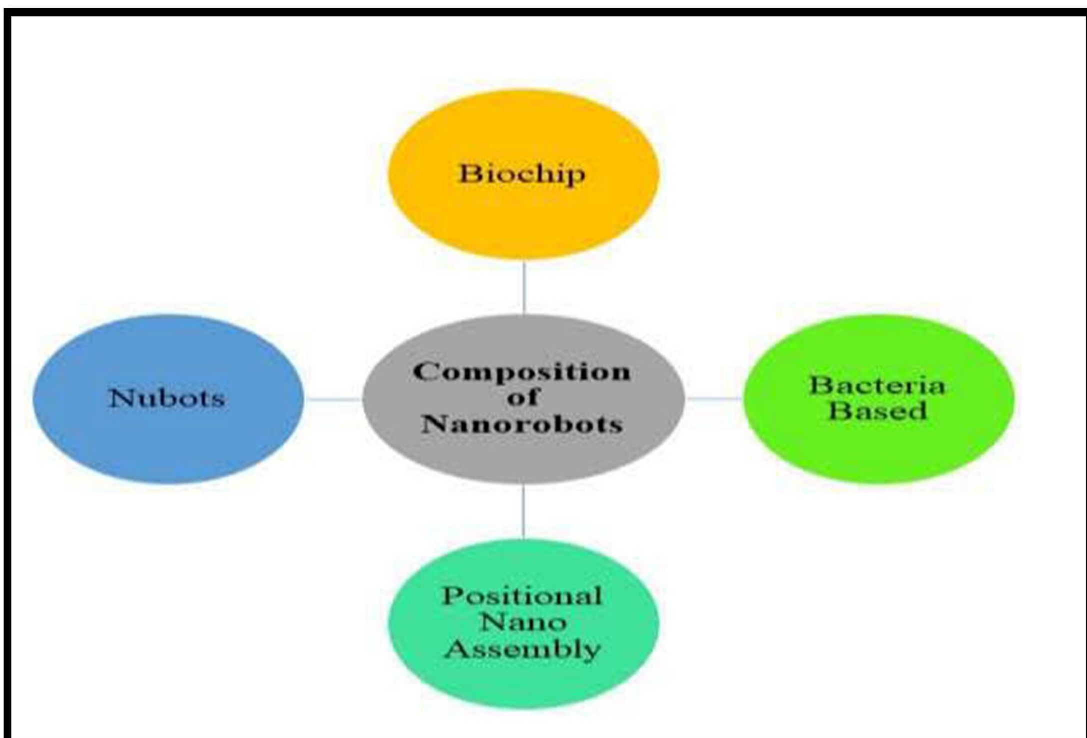

Figure2: Composition Of Nanorobot

D. Nubots (Nucleic Acid Robots)

1) Synthetic nanoscale robotic devices.

2) Examples include DNA walkers developed by various research groups, such as NYU, Caltech, Duke University, Purdue, and the University of Oxford.

Understanding these diverse compositions is essential for advancing the capabilities and applications of nanorobots in various fields, particularly in medicine and nanotechnology[16-18]

IV. MECHANISM OF NANOROBOTS

The exploration of nanorobots with embedded nano biosensors and actuators holds promise for innovative medical devices. The integration of these components aims to provide new tools for biomedical instrumentation, leveraging the advancements in microelectronics since the 1980s. The shift towards integrated medical systems, driven by miniaturization, offers efficient methodologies for pathological prognosis.

The practical application of micro devices in medical treatments and surgery has yielded significant improvements in clinical procedures, particularly in intracranial and heart surgery, where catheterization has become a successful methodology. As we witness the convergence of biomolecular science and manufacturing techniques, there is a notable trend towards miniaturization, transitioning from micro to nano electronics.

Biomedical sensors, operating on cutting-edge technology, form the foundation for designing biomolecular actuators. The ongoing research explores various nanotechnology prototypes for molecular machines, including devices for propulsion and sensing. This multidimensional approach contributes to the evolving field of nanorobotics, paving the way for advancements in medical technologies and procedures.[19-24]

V. APPLICATIONS OF NANOROBOTS

These are the following Applications of Nanorobots:

1) Cancer Detection and Treatment

a) Nanorobots aid in early cancer diagnosis by detecting tumor-producing cells.

b) Address chemotherapy side effects with self-navigation, precise targeting, and localized drug delivery.[8,9]

2) Surgery

a) Minimally invasive surgeries benefit from nanorobots for precise operations at nano, micro, and macro scales.

b) Micro syringes and catheters introduce surgical nanorobots, acting as semi-autonomous onsite surgeons.[10,11]

3) Diagnosis and Testing

a) Nanorobots contribute to early disease identification at the cellular and molecular levels.

b) Collect biological samples for micro-level analyses[12].

4) Gene Therapy

a) Nanorobots serve as gene delivery systems for gene therapy, reaching target sites through blood circulation.

b) Effective interaction with biomolecules facilitates the modification of abnormal genes.[13]

5) Regenerative Medicine and Cell Therapy

a) Magnetically guided nanorobots act as carriers for stem cells, aiding in targeted tissue regeneration.[14]

6) Wound Healing

a) Nanorobots enhance wound healing by delivering growth and clotting factors to chronic wound sites.

b) Magnetically actuated nanorobots assist in blood clot dissolution.[15]

7) Dentistry

a) Nanorobotic dentifrices in mouthwash or gels penetrate sublingual surfaces to combat pathogenic bacteria.

b) Nanorobots induce anesthesia, control nerve sensation, and aid in painless tooth repair, reducing hypersensitivity and curing cavities permanently[26]

8) Neurosurgery

The treatment of cerebral aneurysms in neurosurgery poses significant challenges due to high morbidity and mortality. Nanorobots offer potential solutions by aiding in the screening of new aneurysms or monitoring identified ones, contributing to early detection of tumors and ischemic changes.Addressing spinal cord injuries and nerve damage in neurosurgery is critical for optimizing nerve reconnection outcomes. Nano knife and dielectrophoresis can facilitate axon surgery, supporting the restoration of connectivity with transected axons.[27]

9) Haematology

In haematology, nanorobots play a pivotal role with applications such as Respirocyte, an artificial mechanical red blood cell. Respirocyte performs oxygen collection and diffusion, carbon dioxide collection, and contributes to energy production through glucose metabolism. It exhibits significantly enhanced oxygen-carrying capacity compared to natural red blood cells.
Clottocyte, an artificial mechanical platelet, enriched with blood coagulation proteins, aids in improving physiological homeostasis processes. Microbivores, artificial phagocytes with larger binding sites, demonstrate potent capabilities in trapping various pathogens, including those contributing to septicemia.[28]

10) Vascular Therapy

Nanorobots play a crucial role in screening and monitoring chronic life-threatening conditions like brain aneurysms, unstable atherosclerotic lesions, and lung cancers. Their intravascular navigational ability makes them effective tools for continuous monitoring of tumors, diagnosing vascular abnormalities, and targeted drug delivery for cancer treatment.
With the potential to provide direct therapy to targeted areas, either mechanically or pharmacologically, nanorobots show promise in advancing vascular therapy and overcoming challenges associated with chronic conditions. These diverse applications highlight the versatility of nanorobots in targeted drug delivery, regenerative medicine, wound healing, and various medical interventions.[28,29]

VI. CONCLUSION

Nanotechnology has emerged as a pivotal tool in various medicinal applications, particularly in addressing conditions like diabetes, arteriosclerosis, dentistry, cancer, and gene therapy. The recent advancements in manufacturing technologies have facilitated the development of innovative solutions, emphasizing the potential of nanorobots to effectively tackle biomedical challenges. The intersection of nanotechnology and robotics is evident in the rapidly growing field of robotics, driven by nano-technological advances, contributing to ongoing research, design, and the creation of new robots for diverse practical purposes, both in military and domestic contexts.
The utilization of nanorobots for targeted drug delivery stands out as a promising avenue for the future. This approach holds significant benefits, offering precision and efficiency in delivering therapeutic agents directly to specific cells or tissues. The field of nanomedicine, propelled by these technological strides, holds the promise of achieving earlier diagnoses, improved therapeutic interventions, and enhanced follow-up care. Ultimately, this convergence aims to make healthcare more effective and affordable.
In conclusion, the synergy between nanotechnology and robotics is shaping the future of biomedical applications. The potential of nanorobots in targeted drug delivery, coupled with the broader scope of nanomedicine, indicates a transformative impact on healthcare. As these technologies continue to evolve, they are poised to revolutionize diagnostics, therapy, and overall healthcare delivery, offering new dimensions in the quest for more effective and accessible medical solutions.

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