NANOROBOT: PIONEERS OF PRECISION MEDICINE

ABSTRACT

Nanorobots, or nanobots, represent a revolutionary advancement in the field of nanotechnology. These microscopic devices, typically ranging in size from 0.1 to 10 micrometers, are designed to perform specific tasks at the nanoscale. In the medical field, nanorobots hold the potential to revolutionize diagnostics and therapeutics by enabling targeted drug delivery, minimally invasive surgery, and real-time health monitoring. This review article focuses on nanorobot and their types, core structure and component of nanorobot, natural nanorobot in biological system, nanosubmarine in blood, its applications and current trends of nanorobot in precision medicine. The aim of article has to provide a comprehensive overview of the potential applications and future directions of nanorobot technology. Existing research literature and relevant studies regarding the topic were read and a detailed analysis was undertaken in the indexes of PubMed, Science Direct, MEDLINE, Scopus, and Google Scholar.

Keywords: Nanorobot, Nanosubmarine, Natural Nanorobot, Precision Medicine.

INTRODUCTION[1]

Nanorobots, or nanobots, are theoretical which are constructed on the nanoscale (typically ranging from 1 to 100 nanometers). These tiny machines are visualize to perform specific tasks at the molecular or cellular level. With the rapid advancement of nanotechnology and materials science, micro/nano robot has role in various fields of biomedicine .These diminutive robots can penetrate deep or inaccessible regions within our bodies, conducting various medical procedures, and showcasing great promise in areas such as diagnosis, drug delivery, and surgery. Here are some types of nanorobots that have been conceptualized or are under development[1].

TYPES OF NANOROBOTS[2]:

1. Medical Nanorobots: These nanobots are designed for targeted drug delivery, precise surgery at the cellular level, or even repairing damaged tissues. They could potentially navigate through the bloodstream to deliver drugs directly to cancer cells or other diseased tissues, reducing side effects and increasing effectiveness.

2. Molecular Assemblers: Molecular assemblers are nanobots that can manipulate atoms and molecules to build complex structures.

3. Swarm Nanorobots: These are large groups of nanorobots that work collectively, often resembling natural swarms like insect colonies. Swarm nanorobots could be used for tasks such as environmental monitoring, disaster response.

4. Respirocytes: Respirocytes are hypothetical nanorobots designed to mimic the function of red blood cells. They would be able to carry and deliver oxygen and remove carbon dioxide from the bloodstream more efficiently than natural red blood cells.

5. Utility Fog: Utility fog refers to a hypothetical collection of nanorobots that can reconfigure themselves into any shape or form, essentially creating programmable matter.

6. Nano-Scale Sensors: Nanorobots equipped with sensors could be used for various purposes, such as detecting and diagnosing diseases at very early stages[2].

STRUCTURE OF NANOROBOT[3]

The core structure of a nanorobot typically consists of several key components that enable it to function effectively at the nanoscale.These components work together to enable nanorobots to perform their intended tasks, whether it's delivering drugs to specific cells, assembling molecular structures, or sensing environmental changes.

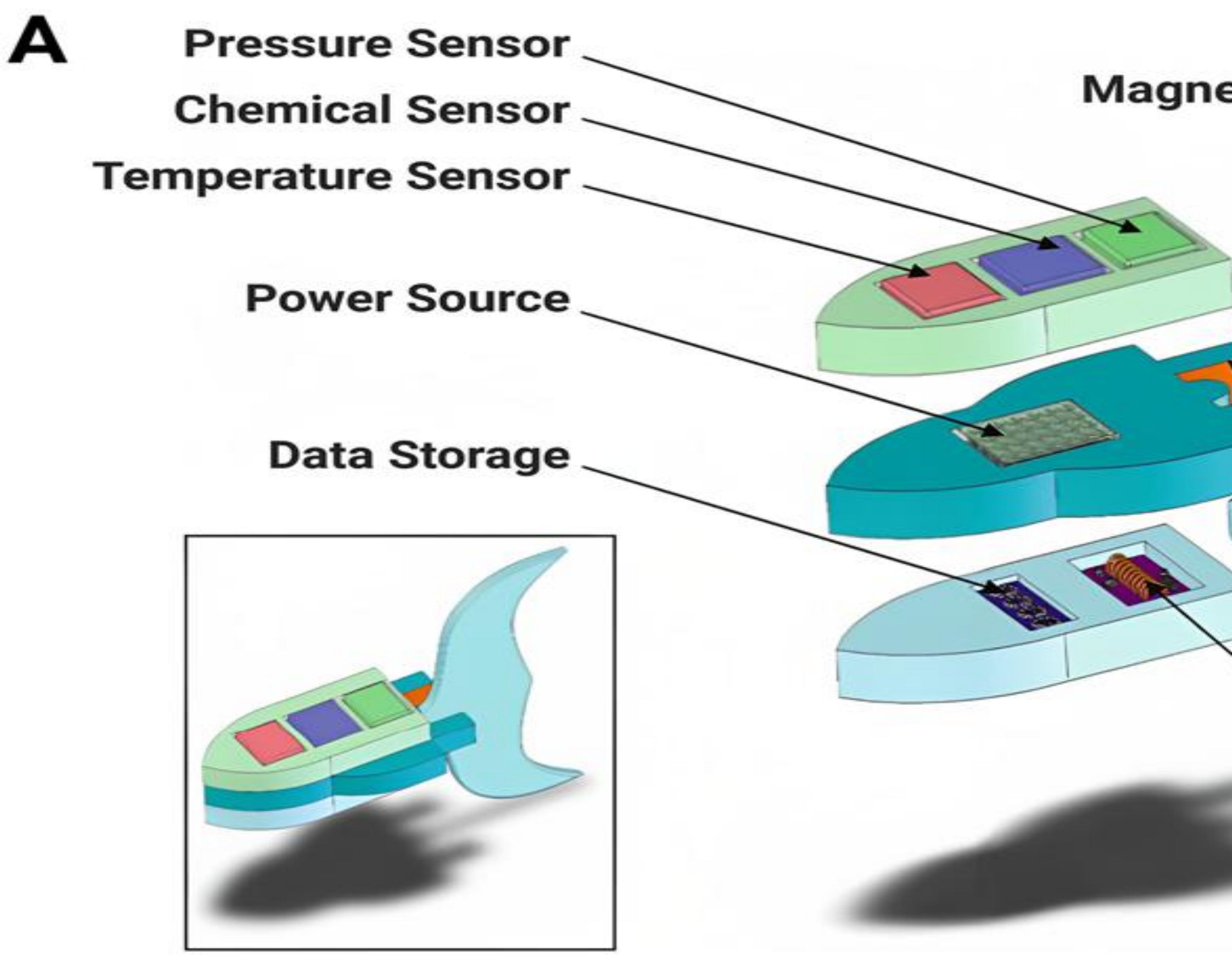

Figure 1: **Core structure of nanorobots with their components**[3]

1. Power Source: Nanorobots require a power source to operate. This could be in the form of a small battery, a miniaturized fuel cell, or even energy harvested from their environment (such as glucose in the bloodstream for medical nanorobots).

2. Sensors: These sensors could detect chemical signals, temperature changes, mechanical stress, or other relevant data depending on the nanorobot's purpose.

3. Actuators: Actuators are mechanisms that allow nanorobots to move or manipulate their surroundings. This might include tiny motors, piezoelectric elements for precise movement, or mechanisms for gripping or releasing substances.

4. Control System: control system contain a microprocessor or a similar device that processes sensory information, makes decisions and coordinates the actions of the nanorobot.

5. Communication Module: Communication is essential for nanorobots for operating in complex environments. Communication modules could enable nanorobots to exchange data with each other, with external devices, or with a central control unit.

6. Structural Components: The physical structure of a nanorobot is often made from durable materials such as carbon nanotubes, polymers, or other nanoscale materials. These components need to be strong yet lightweight to withstand the conditions they operate in.

7. Payload or Tools: Depending on their intended application, nanorobots may carry payloads such as drugs (for medical applications), nanoparticles (for targeted delivery or sensing), or specialized tools (for molecular assembly or manipulation).

8. Safety Features: nanorobots have biocompatible coatings to prevent adverse reactions in the body[3].

NATURAL NANOROBOT IN BIOLOGICAL SYSTEM[3]

In biological systems, there are several examples of natural structures that can be considered as nanorobots due to their intricate and specialized functions at the nanoscale. These natural nanorobots can enhance our understanding of fundamental biological processes and also inspires advancements in nanotechnology and nanomedicine.

Here are a few notable examples:

1. Flagellar Motor: Bacteria such as Escherichia coli (E. coli) possess a flagellar motor, which is a molecular machine that rotates a helical flagellum to propel the bacterium through its environment..

2. ATP Synthase: present in the inner membranes of mitochondria and in the plasma membranes of bacteria. ATP synthase is a molecular machine responsible for producing adenosine triphosphate (ATP), the primary energy currency of cells.

3. Ribosome: Ribosomes are cellular complexes responsible for protein synthesis. Ribosomes are composed of RNA and protein molecules arranged in a highly organized structure, where the process of translation occurs with precision at the nanometer scale.

4. Clathrin: Clathrin is a protein complex involved in the formation of coated vesicles in cells. These vesicles transport molecules within the cell by selectively engulfing and then releasing it at its destination.

5. Virus Capsids: Viruses are nanoscale infectious agents that consist of a protein shell called a capsid, which encloses their genetic material. Capsids are highly structured and precisely engineered to protect the viral genome during transmission between host cells[3].

APPLICATIONS OF NANOROBOT[3]

Nanorobots, or nanobots, have a wide range of potential applications across various fields due to their ability to operate at the molecular and cellular levels.

Some of these applications are still in early stages of research and development but ongoing advancements in nanotechnology can expand the possibilities for their practical use in the future. Here are some key applications of nanorobots:

1. Medicine and Healthcare:

- **Targeted Drug Delivery:** Nanorobots can deliver medications directly to specific cells or tissues, reducing side effects and improving treatment efficacy. They can navigate through the bloodstream or be injected into specific sites.

- **Cancer Therapy:** Nanorobots could target cancer cells more precisely and deliver drugs directly to tumors or even performing localized treatments such as thermal ablation or photodynamic therapy.

- **Surgery and Tissue Repair:** Nanorobots may enable minimally invasive surgeries at the cellular level, assisting in tissue regeneration, wound healing.

2. Biomedical Sensing and Imaging:

- **Diagnostic Tools:** Nanorobots equipped with sensors could detect biomarkers of diseases at early stages, providing rapid and accurate diagnostic information.

- **Imaging Agents:** Nanorobots can act as contrast agents for advanced imaging techniques such as MRI, CT scans, or molecular imaging, enhancing visibility of tissues and cellular structures.

3. Environmental Monitoring and Remediation:

- **Pollutant Detection**: Nanorobots can detect and monitor environmental pollutants or contaminants at a molecular level, providing real-time data for environmental assessments.

- **Nano-Scale Cleanup:** Nanorobots could be used to clean up oil spills, degrade pollutants, or remediate contaminated water and soil.

4. Industrial and Manufacturing Applications:

- **Nanomaterials Synthesis:** Nanorobots may facilitate precise manufacturing of nanomaterials.

- **Quality Control:** Nanorobots could inspect and ensure the quality of manufactured products at a molecular level.

5. Information Technology:

- **Data Storage:** Nanorobots could store vast amounts of data at the molecular scale, potentially revolutionizing data storage technologies.

- **Computing:** Nanorobots might be integrated into future computing systems, enabling ultra-compact and energy-efficient computing devices.

6. Defense and Security:

- Sensing and Surveillance: Nanorobots could be helpful in detecting chemical or biological threats in sensitive environments[3].

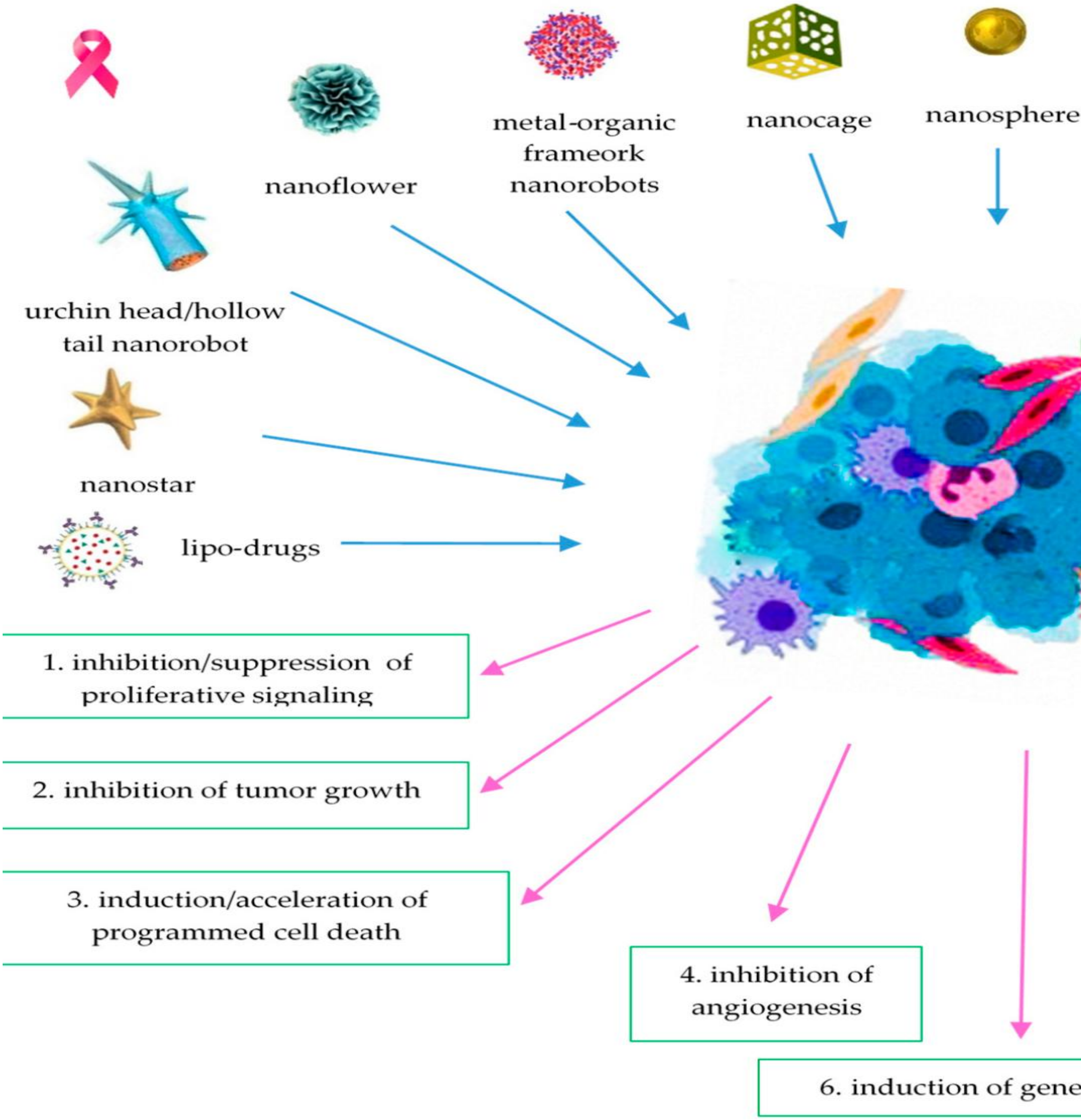
metal-organic
frameork
nanorobots
nanocage
nanosphere
nanoflower
urchin head/hollow
tail nanorobot
nanostar
lipo-drugs
1. inhibition/suppression of
proliferative signaling
2. inhibition of tumor growth
3. induction/acceleration of
programmed cell death
4. inhibition of
angiogenesis
6. induction of gene

Figure 2: Breast cancer hallmarks targeted by naorobots[4].

NANOSUBMARINES IN BLOOD[3]

Nanorobots can be injected into human blood vessels and become molecular robots which could often described as “nanosubmarine”. These nanosubmarines derive energy from glucose and oxygen dissolved in the blood and are programmed by the physician to detect any object they encounter through externalacoustic signals. Molecular nanosubmarines can perform whole-body health checkups. They can unblock blood clots in blood vessels and remove lipid deposits in the heart and arteries. They can engulf germs, kill cancer cells, and monitor lesions in the body. Nanosubmarines can also be used to perform human organ repair work, such as repairing damaged organs and tissues and performing cosmetic surgery[2].

CURRENT TRENDS OF NANOROBOTICS IN PRECISION MEDICINE[2]

1. Targeted Drug Delivery:

- **Enhanced Targeting Strategies:** Nanorobots are being designed with advanced targeting mechanisms, such as surface modifications with specific ligands (e.g., antibodies or peptides), to selectively deliver drugs to diseased cells or tissues while sparing healthy ones.
- **Multi-Functional Nanorobots**: nanorobots that can carry multiple drugs or therapeutic payloads simultaneously, enabling combination therapies.

2. Diagnostic Applications:

- **Biosensors and Imaging:** Nanorobots equipped with biosensors can detect biomarkers associated with diseases like cancer at early stages.
- **In Vivo Imaging:** Nanorobots are being developed as contrast agents for advanced imaging techniques (e.g., MRI, CT scans) to enhance visualization of tissues and cellular structures.

3. Regenerative Medicine:

- **Tissue Engineering:** Nanorobots can assist in scaffolding, construction, cell differentiation, and tissue regeneration processes.
- **Drug-Free Therapies**: Some nanorobots can stimulate tissue repair mechanisms, potentially offering drug-free therapeutic alternatives.

4. Microsurgery and Intervention:

- **Minimally Invasive Procedures**: Nanorobots are visualized to perform microsurgical tasks within the body, such as targeted tissue biopsy, removal of blood clots, or repairing damaged tissues with high precision.
- **Endovascular Interventions:** In cardiovascular medicine, nanorobots could navigate through blood vessels to treat blockages or aneurysms without the need for open surgery.

5. Smart Nanorobots:

Advances in artificial intelligence and nanotechnology enable nanorobots to navigate through complex biological environments, responding to changes and adapting their behaviour accordingly.

6. Challenges and Future Directions:

- **Biocompatibility and Safety:** Nanorobots are biocompatible and do not trigger immune responses or toxicity remains a significant challenge.

- **Clinical Translation:** From experimental studies to clinical applications, we have to overcome regulatory hurdles, scaling production, and demonstrate safety and efficacy in human trials.

- **Ethical Considerations:** As with any emerging technology, ethical concerns regarding patient consent, privacy, and equitable access to nanorobotic treatments need to be addressed[1].

CONCLUSION

The main target of writing this review was to provide an outline of the development ofnanotechnology in medicine by making a nanorobot and introducing it as a newmode of drug delivery.

Cancer treatment is most likely the driving force behind the creation of nanorobotics. To decide the prognosis and chances of survival in a cancer patient, better prognosis can be achieved if the evolution of the disease is time-dependent and timely diagnosis is made. Another important aspect is to reduce the side effects of chemotherapy on the patients by forming efficient targeted drug delivery systems. Programmable nanorobotic devices are working at the cellular and molecular level would help doctors to carry out precise treatment. In the future, simple structured medical nanorobotsare expected to evolute and become more sophisticatedand capable of performing multiple medical functionsand tasks, ultimately becoming true nanosubmarines in the bloodstream.

REFERENCES

1) Sun T, Chen J, Zhang J, Zhao Z, Zhao Y, Sun J and Chang H (2024), Application of micro/ nanorobot in medicine.

2) Aggarwal M, Kumar S (September 20, 2022) The Use of Nanorobotics in the Treatment Therapy of Cancer and Its Future Aspects: A Review. Cureus 14(9): e29366

3) Kong X, Gao P, Wang J, Fang Y, Hwang KC. Advances of medical nanorobots for future cancer treatments. Journal of Hematology & Oncology. 2023 Jul 14;16(1):74.

4) www.google.com.