NANOROBOTS: AN EMERGING TOOL IN MEDICAL SCIENCE

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ABSTRACT

This article aims at giving summary on the present prominence of Nanomedicine in medical science. Now a day medical science is developing various new scientific innovations. Nanomedicine is such a field which helps to change the vision of the medical science. Nanorobotes is the part of the Nanomedicine which is an outstanding tool for future medicine. It is defined as, any smart structure which is capable of actuation, sensing, signaling, information, processing, intelligence, management and swarm performance on Nano scale (10-9m). Nanorobots are very tiny thusthey can simply carry the various drugs and go across the human body. Researchers report that the external part of nanorobots willpossibly beassembled of carbon atoms in a diamond structure. Super smooth surfaces will minimize the chances of stimulating the immune system of the body. We also summarize briefly medicinal application of the nanorobots.It is used in the cancer treatment which carry and transport large amounts of anticancer drugs into cancerous cells and reduces the side effect related to the current conventional chemotherapy. Diseases such as neoplasm, hepatitis, diabetes, pulmonary, dentistry and cancer can be used this nanorobotics technology. Nanorobots are also used in the area of dentistry.It helps ininducing oral analgesia, desensitize the tooth, straighten the irregular set of the teeth and improve durability of the teeth. Medical nanorobots can willingly treat genetic diseases.

The aim of this review paper is to give an overview on the field of Nanorobots based on papers published in the last three decade. References to earlier publications on this topic can be found in citing papers published up from 1992 untill 2019. The present review article is an attempt to provide comprehensive knowledge about various aspects and details about Nanorobotics. To make this review various national and international books,some journals and various websites for collecting the information regarding nanorobots. These articles probably focus on the nanorobots and its various tools, its components, mechanism and application of the nanorobots in medicinal science. In addition, the existing study comprises the prospect aspects of the nanorobot.

Key words –Nanomedicine, Nanorobotes, Nano scale, Anticancer drugs

INTRODUCTION

Nanotechnology is the study, design, creation, synthesis, manipulation and application of materials, devices, and system at the nanometer scale (1m consists of 1 billion nanometers). Nanotechnology is a scientific study of effect of matter on an atomic as well as molecular scale[1].Nanomedicine is the part of the nanotechnology, which is helping to change the vision of the medical science by improving the various scientific innovations. Nanomedicine deals the overlook of human syndromes and the progress the biological system by means of engineering Nano scale robots that travel from all over human bodies. Nanorobot is a new technique that redefined conventional process. Also by developing a micro scale delivery system, we hope to replace a need for traditionalmethods and instruments.

Nanomedicine is the procedure of detecting, treating and inhibiting disease and traumatic damage of relieving pain and of conserving and improving human health, using several molecular tools as well as molecular knowledge[2].

Theory of nanorobots-

According to nanorobotic concept "Nano robots are microscopic in size, it would possibly be essential for very large numbers of them to work together to perform microscopic and macroscopic tasks" [3,4].Nanorobotics is the creating the robots at the scale the nanometer or micrometer.It is the emerging field which is used for medical application.This is a nanoelectromechanical system created to perform a specific task.Nanoroboticsisa more advantageous technology than the conventional medicine.

Nanorobots are very tiny because theycan certainly travel over the human body. Scientist reports the peripheral of a nanorobot will likely bring together of carbon atoms in a diamond structure. Super smooth surfaces will minimize the chances of triggering immune system of the body and permit the nanorobots to go almost their business without hindrance[5].

Advantages of Nanorobots-

Advantages of the nanorobots over current methods are discussed following.

1) In treatment of cancer, onlytumor cells are treated by nanorobots without damaging to healthy cells. Hencenanorobots are used as targeted therapy in cancer.
2) The nanorobots are very durable.Theorotically; they can operate for years without any damage owing to their miniature size, which reduces mechanical damage.
3) Nano robots are environment friendly because is produces slight pollutions from production.
4) It can guide externally or as per program, targeting specific locations hence it is used as targeted therapy.
5) In any of invasive technique, the patient's life is totally in hand of surgeon. It is risky, as one mistake could influence disaster.Nanorobots can guide as per program an account of computerization. Hence less erroroccurs.

6) Nanorobots are so tiny, it can deliver various drugs, and hence it provides better availability of drugs.
7) Some harmful diseases such as HIV, Cancer, and diabetes can be cured by nanorobotes with the help of nanoroboticstechnology.
8) Nanorobots are so tiny thus they can complete works faster than larger robots.
9) A drug molecule are passed by nanorobots and released where needed, the advantage of large interfacial area during mass transfer can be recognized.
10) Nanorobotscan guide externally hence useful for monitoring, detecting and fighting diseases.

Disadvantages of Nanorobots-

The disadvantages of the nanorobots are as follows.

1 The costfor the designing ofnanorobots is high.

2 The designingofthenanorobot is very difficult.

3 It is hard to interface, modify and design and is complex.

4 Privacy is the other possible risk involved with nanorobots[6,7].

5 Electrical system can create stray fields which canpossiblymake active bio- electrical based molecular recognition system[8].

6 In the field of terrorism, nanorobots can cause a vicious risk.

Components of the nanorobots-

The various components of the nanorobots are mentioned in the figure.1

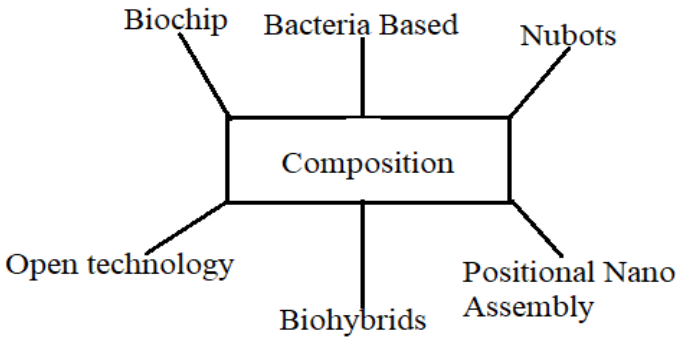

Fig.1: Components OfNanorobots[50]

1) Biochip

Synthesis includes the combination of nanotechnology, photography and new biomaterials. It can be used for manufacturing of nanorobots for various medical applications. This medical application involves surgical instrumentation, diagnosis and delivery of several drugs. Nanotechnology has prepared biochips which have various applications for commercial purpose, where biochips can be inserted inthe body and helps to transfer the information and observe any biological changes in-vivo. Electronics industries currently use biochip for manufacturing. Biochip is inserted into nanorobots can be integrated into Nano electronics devices which will allow tele-operation and advanced skills for medical instrumentation [8].

2) Bacteria based

This approach uses biological microorganism like Escherichia coli bacteria. In this model a flagellum is usedfor propulsion purpose. The electromagnetic field is generally applied to regulate the motion of this biological integrated device.[9,10]

3) Nubots

Nubots are manmademachinelike devices on the Nano scale. Nubots is an acronym for Nucleic acid robots. TOassemble2D and 3D Nano mechanical devices, DNA structure is provided. By using, proteins,small molecules and other molecule of the DNA this DNA based machine can be activated.Nubots involves DNA structure,asa carrier for targeting drug delivery[12,13].

4) Open technology

An article with a scheme of Nano biotech development using open technology approaches has been addressed to the United Nations General Assembly. According to the document sent to UN, Linux and Open Source has in modern years faster the progress of computer systems, a similar approach should be useful to the society at great and speed up nanorobotics development[13,14].

5) Biohybrids

The bio - hybrid system is the developing field which is the combination of artificial structural components and biological components for biomedical and robotic applications. The componentsof bio-nanoelectromechanicalstructures areinnanoscalesize, for example DNA, protein [15].

6) Positional Nano assembly

Robert Freitas and Ralph Merklewere established a Nano factory cooperation in 2000,which is a focused continuing work comprising 23 researchers from 10 organizations and 4 countries. This researcher developsa practical research program having aim is develop positionally controlled diamond mechanosynthesis that would be accomplished by constructing diamondoid medical nanorobots[16].

Nano- fabrication and mechanism of action-

Nanorobots in medicine are used for the purpose of conserving and protecting the human body against pathogens. They are 0.5 – 3 μ in diameter and are assembled of parts with dimensions in the range of 1 to 100 nm. The carbon is the main component used in the form of diamond orfullerenes.Nanocompound due to hisimproved strength and chemical inertness. Oxygen, nitrogen is some light components may be used for particular purposes. The external passive diamond covering provides a smooth, sound coatingAlso, this external passive diamond induces less reaction from the immune system.

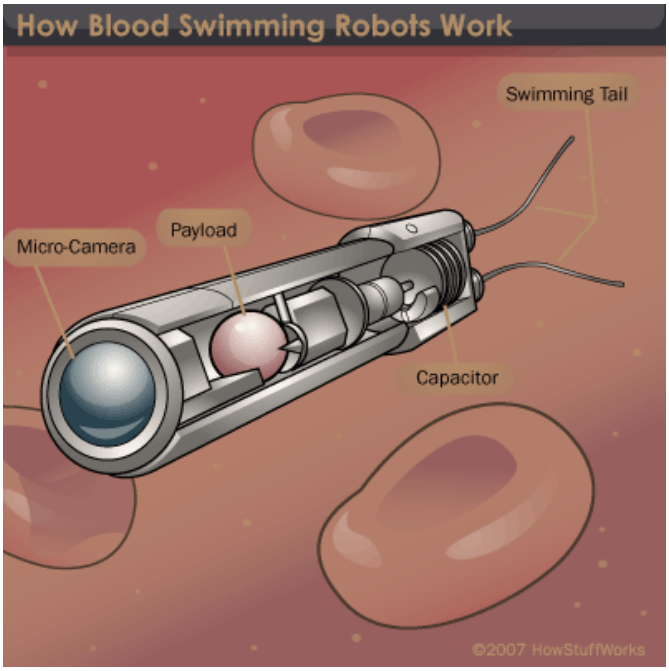

Fig.2:Mechanism of Nanorobots[47,48,49]

Nanorobots can be poweredfabric down of local glucose, oxygen and sound energy which supplied externally. They can be controlled by onboard computers. Communication with device canattain by broadcast type audio signaling. A navigational set-up fixed in the body, which is responsible for high accuracy and keep trajectory of the various devices in the body. Nanorobots are capable to make a distinction between diverse cell by examining their surface antigens. Nano robots can be fabricated by the use of various parts like sensors, actuators,power, communications and interfacial signals through longitudinal scales and between organic or inorganic alongside with biotic or abiotic systems. Nano actuators can be monitored by electrical signals[17,18].

When the mission of the Nano robots is over, they can be recovered by permitting them to effuse themselves. They can also be detached by active scavenger systems.

Nano robot Architecture:

The medical Nano robot for Biohazardresistance should consist of a set of application-specific integrated circuit block. The structural design of nanorobot has,providedasynchronous interface for antenna, sensor, and a Nano processor, which is able to deliberate actuator and ultrasound communication activation when suitable. The number

of Nano devices to integrate a Nano robot must keep the same hardware sizes with respect to the inside body operation applicability [19,20].

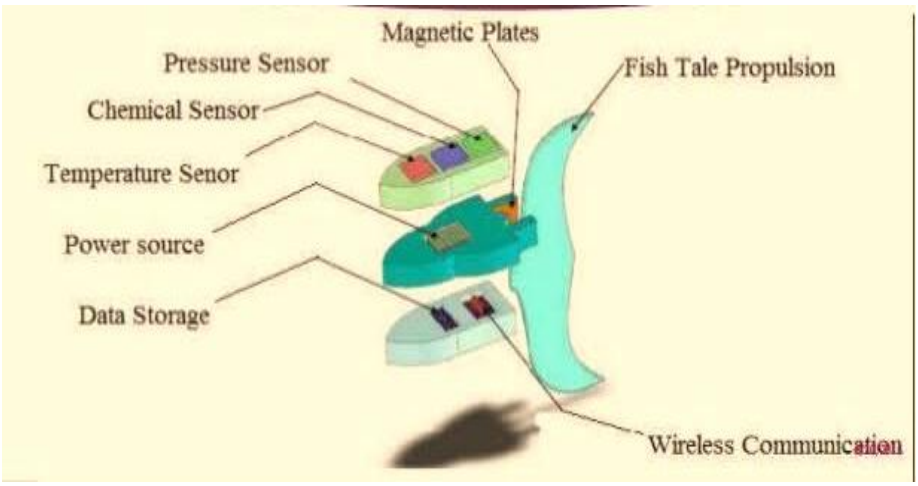

Fig.3:Architecture of Nanorobots[51,52]

Medical and pharmaceutical applications-

Nanorobots are composite machine used for diagnosing, treating and preventing diseases relieving pain, preserving and improve human health. The detail applications of the nanorobotsare explained below.

In Dentistry

Nanodentisry is a novel field which is primarilylaunched to develop interest in future of dentalapplications nanotechnology. Todevelop interest in the future.Principal to launch of novel field. Dental nano robots can be beneficial for preventing, healing and curative procedures. This dental nanorobot helps to desensitize the teeth, convincing oral analgesia, desensitize teeth, and straighten teeth. The dental nanorobots can perform the following applications.

1) Maintenance of oral hygiene-

A mouthwash containing smart nanorobots could detect and finish pathogenic bacteria where as permitting the innocuous flora of the mouth to flourish in a healthy ecosystem. Additionally the nanorobots can identify food particles and plaque and removed this food particle and plaque from teeth to be cleaned away. Also, they prevent tooth decay[21].

2) Cavity preparation and Restoration

Various nanorobots in work on the teeth in unison, too small to see the naked eye, can be used for cavity preparation and repair of teeth.This cavity preparation is specially controlled to the demineralized enamel and dentin, consequently, given that the full protection of complete tooth structures.

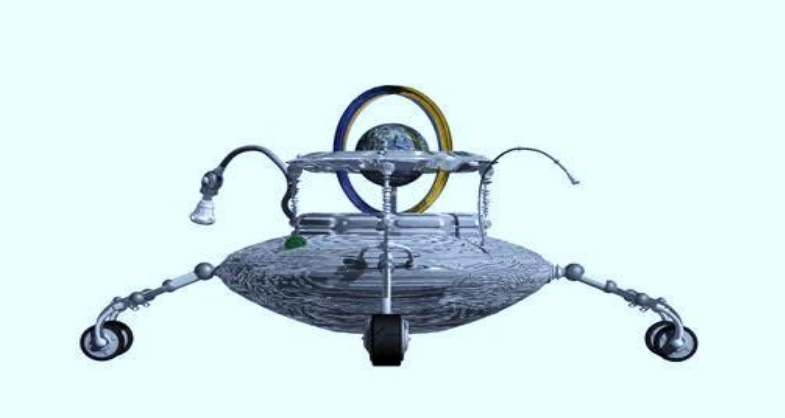

Fig.4:DentalNanorobots[49,50].

3) Tooth repair-

Nanodentalconsist of various engineering techniques such as genetic engineering, tissue engineering, tissue regeneration processes for s primary tooth repair. Nanorobots provide comprehensive dentition replacement therapy containing mineral in addition to cellular components.

4) Dentin hypersensitivity

Dentin hypersensitivity is a pathological condition caused by pressure transferred hydrodynamic to the pulp. Reconstructive dental nanorobotes selectively and accurately block specific dentinal tubules within minutes,offering patients a rapid and long-lasting cure from hypersensitivity.

5) Esthetic Dentistry

Dental Nanorobotsiscastoff for dentition re-naturalization techniques in esthetic dentistry. They dig out old amalgam repairs and remanufacture teeth. Biological materials are used in manufacturing for make a distinction from original teeth.

6) Tooth repositioning

Orthodontic nanorobots can operate the periodontal tissue,containing gingiva, periodontal ligament,cemented and alveolar bone permitting quick and painless tooth straightening, replacement and repositioning in minutes to hours[22].

In Cancer Detection and treatment-

Cancer could be defined as the group of the diseases categorized by the uncontrolled growth and spread of abnormal cells in the body. Cancer medicines, when formulated as nanoparticles, have more advantages than when in taken as free drugs. They are specific to the diseased cells; they have no side effects, they increase the solubility of some hydrophobic drugs, they can penetrate inside cells and so on[23].The clinical application of the nanorobots in cancer is the diagnosis and treating the carcinogenic cells. Cancer treatment

is most likely the main reason for the development of the nanorobotics. With the help of the nanoroboticscancer can be effectivelycured with recent stages of medical skills and the various therapy tools. Nanotechnology holds tremendous potential for overcoming many of the problems that conventional methods face in the treatment, diagnosis and detection of cancer[24].The several chemical biosensors are inserted into the nanorobtswhich can be used to carry out the finding of the tumor cells in the early stages of development by detecting the intensity of the E-cadherin signals inside the patient's body[25].

Another important feature of nanorobots in cancer is that, it can achieve an effective cure for patients by developing effective targeted therapies to drop the side effect from existing chemotherapy. Nanrobotscantransfer and deliver large quantities of anticancer drugs into malignant cells without damaging healthy cells.

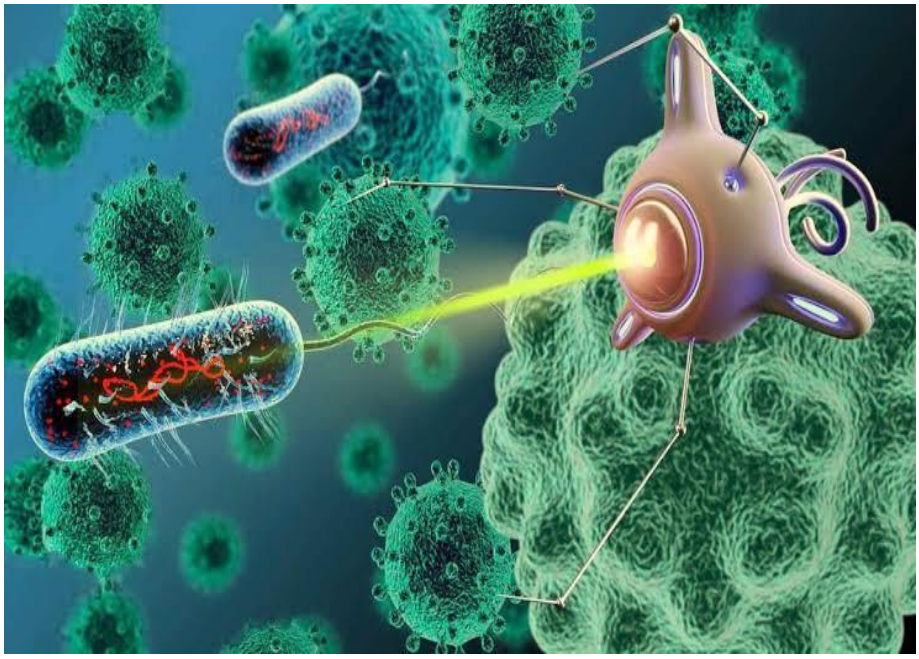

Fig.5: Cancerous cells killed by Nanorobots[45]

In the diagnosis and treatment of Diabetes-

To maintain the human metabolic rate functioning healthfully,the glucose passed through the blood circulation is essential and its exact level is a main problem in the diagnosis and treatment of diabetes.

The hSGLT3 molecule can help to express the glucose levels for diabetes patients. For identification of glucose, this protein works as sender.

The simulated nanorobot archetype model has inserted Complementary Metal Oxide semi-conductor (CMOS) Nano Bioelectronics. It features a size of ~2µm, which permits it to run freely inside the body. Whether the Nano robot is invisible or visible for the immune reactions, it was no interfering for identifyinglevels of glucose in blood. For the monitoring of glucose thenanorobot uses implantedchemosensor that includes the inflection of hSGLT3 protein glucosensor action. Through its chemosensor, the nanorobot can identify that the patient has wanted to inject insulin or not. If needed, medication clinically suggested by the nanorobots.

In architecture of medical nanorobots, measured data can be then transferred automatically through the RF signals to the mobile phone passed by the patient. At any time, if the glucose attains acute levels, the nanorobot gives off an alarm through the mobile phone. In the simulation, the nanorobot is planned similarly to emit a signal based on definite lunch times, and to measure the glucose levels in preferred intervals of time [26].

In surgery

Surgical Nano robots could be implanted into the human bodythrough the vascular system. [27,28]. A surgical Nano robot, are monitored by a human surgeon which can act as a semi-autonomous on-site surgeon insidethe body. Examining for pathology and then diagnosing and improving scratches by Nano manipulation, are the several functions of such devices and it can be controlled by an on-board computer while keeping communication with the controlling surgeon by the use ofcode ultrasound signals [29,30].

In brain Aneurysm

For brain aneurysm diagnosis, Nano robots essential to path the vessel endothelial damage in advance a subarachnoid hemorrhage occurs. These modifications on chemical concentration are used to monitor the Nano robots to detect brain aneurysm in the early stages of development[31].

Nanomedicine

Early detection and targeted therapy for cancer, biomedical equipment's, surgery, checking of diabetes, and health care are various uses of nanorobots in medicines. In such planning, forthcoming medical nanotechnology is predictable to employ Nano robots inserted into the patient to carry out treatment on a cellular level. Such Nano robots proposed for use in medicine would be non-replicating[32]as replication would unnecessarily increase device complexity, decrease consistency and hamper with the medical mission. Instead, medical Nano robots are recommended to be fabricated in hypotheticals, carefully controlled nano factories in which Nano scale machines would be firmly integrated into a thought desktop scale [33] machine that would construct macroscopic products.

Nano Impression

Impress material is accessible by nanotechnology application. Nano filler is incorporated in the vinylpolysiloxanes, creating a distinctive addition siloxane impression material. It has better flow; improved hydrophilic properties are the main advantages of these materials, hence less voids at boundary and improved detail precision[34].

In gene therapy

Medical nanorobots are treating genetic diseases by linking the molecular structures of DNA and proteins which are found in the cell identify reference structures. Any abnormalities can then be rectified. In some cases, chromosomal replacement therapy is more in effect than in cytorepair. Floating inside the nucleus of a human cell, an assembler-built repair vessel carries out some genetic preservation. Elongation of a supercoil DNA occurs between its lower pair of robot arms,and the nanomachine gently stretch the unwound strand through a gap in its prow for investigation. Upper arms, meanwhile, remove regulatory proteins from the chain and place them in an intake port[35].

The structures of both DNA as well as proteins are related to information stored in the database on a bigger Nano computer situated exterior the nucleus and attached to the cell-repair ship by a communications link. If irregularities are creating in any structure, then this is rectified and the proteins reattached to the DNA chain, which is back away to its initial form. Through a diameter of 50 nanometers, the repair vessel would be lesser than furthermost bacteria and viruses, however, capable of treatments and cures well away from the reach of present-day physicians. With trillions of these machines running through a patient's bloodstream, "internal medicine" would take on new consequence. Disease would be attacked at the molecular level, and such conditions as cancer, viral infections and arteriosclerosis could be spread out.

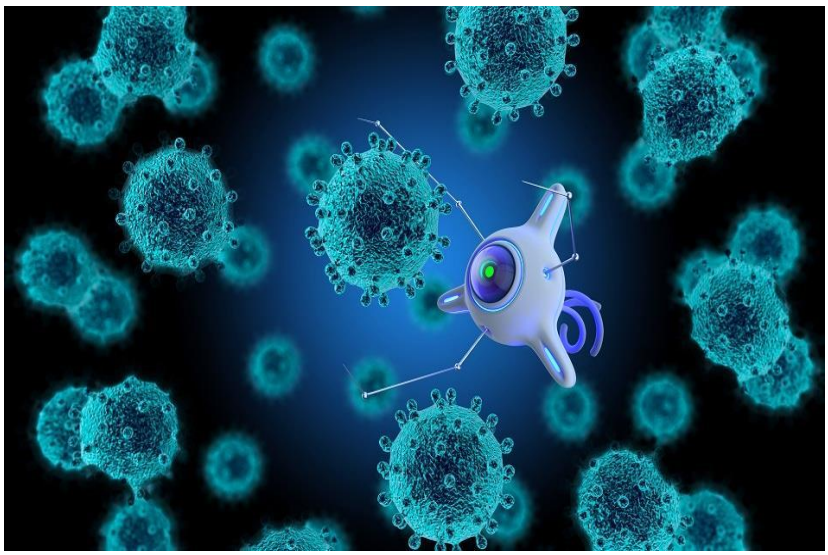

Fig.6:Nanorobots used in gene therapy[43,44]

Diagnosis and testing

Medical nanorobotshaving an enormous range of functions such as diagnostic, testing and monitoring functions, in tissues as well as in the blood. All vigorous signs containing temperature, pressure, chemical composition, and activity of the immune system, from all diverse parts of the body could constantly record and reported by the nanorobots.

Nanorobotsacceptable by a patient for diagnostic purposes approach the surface of the stomach lining to begin their examine for signs of infection [36].

As Artificial phagocyte (Microbivore)

Microbivore is a small microscopic size, artificial mechanical phagocyte whose principal function is to abolish microbiological pathogen found in the human blood stream. The main function of the micribivore is to wipe out microbiological pathogen like viruses, bacteria, and fungi found in the human blood stream, by “digest and discharge” process. They could digest the unwanted microbiological pathogen. Microbivore can achieve complete clearance of most severe septicemic infections in hours, when given IV [37].

Cell repair and lysis (Chromallocyte)

Chromallocyte is a one more type of nanorobot which would replace whole chromosomes in distinct cells, thus reversing the effect of genetic disorder and other accrued damage to our genes, inhibiting aging, They would able to healing whole cells, organs and restore health.[38].

As Artificial Neurons

Nano robots can be employed in substituting every neuron in one's brain with nanorobot which is intended to function just like normal, everyday, natural neurons. The nanotech neurons are functionally the same. They link to the same synapse and do the same functional starring role[39].

Magnetic nanoparticles

The prospective of magnetic nanoparticles stems from the fundamental characteristics of their magnetic cores collective with their drug loading capability, biochemical properties. the modern advancement of magnetic nanoparticles for drug delivery, focusing chiefly on the impending applications like targeted drug delivery, bioseparation, ,magnetic resonance and cancer diagnosis, induction of hyperthermia, induction of hyperthermia, nanorobotic agents ,tissue engineering ,artificial muscle ,magnetically activated polymers, controlled tissue assembly, control cell function, bone regeneration scaffold ,destruction of blood clots ,labeling stem cells with magnetic nanoparticles, implant-assisted intrathecal magnetic drug targeting, biodegradable magnetic nanocomposite stent, local drug delivery etc.[40]

Gout

Gout is a state characterized by the peculiarly higher amount of uric acid in blood, frequent attack of joint inflammation (arthritis), hard pieces of uric acid set down in the joints, and reduced kidney function. In this condition kidney lose the capacity to eliminate the waste from the breakdown of fats from the blood stream. This waste left around the joints, specially knee and ankles. Nano robots can break up these crystals in joints and relief from symptoms, though it wouldn't be capable to inverse the state permanently.

Kidney stones

It can be extremely painful, bigger the stone the more difficult to pass. A Nano robot having the ability to breakdown of such kidney stones by means of a smaller laser.

Cleaning wounds

Nanorobots can help to remove debris from the wounds, decreasing the risks of infection. They would be mainly useful in cases of perforation of lesions, where it can be not be possible to treat by various conventional methods.

Atherosclerosis

Atherosclerosis is a condition is which the arteries become hard and narrowing due to buildup of plaque in the arteries which restrict the blood flow. Medical nanorobot have capability that they can very easily find the atherosclerotic lesion blood vessels,and treat them chemically or pharmacologically[41].

Hemophilia

The syndrome in which blood does not clot generally called as hemophilia. When blood can not clot generally, unnecessary bleeding (internal and external) occurs after any damage. A special type of nanorobot called clottocyte which transmits a small mesh net that softens into a tacky membrane upon contact with blood plasma [42].

CONCLUSION-

This article aims at giving an overviewof the current position of nanorobotics in the medical science. Nanorobotics helps to change the vision of the medical science by improving the scientific discovery. They will provide combine actions they helpin diagnosing, treating and preventing disease, relieving pain, conserving and improving human well-being various molecular tools and molecular information of the human body.Nanorobots have a numerous advantages inthedelivery of drugs over a present method. These includeimproved bioavailability, targeted therapy, less surgeon mistakes, better accuracy, fewer side effects and rapid speed of drug action. A few application discussed in this article have already been established and are now helping patients in all over the world. It includes cancer, diabetes, cardiovascular diseases, neurogenerative and psychiatric disease,viral infections, kidney stones, gout, atherosclerosis, hemophilia and dental applications.

Nanotechnologyhelps in the future to cure a many diseases that will not cure today. As future research continues in this field, more diagnostic and treatment methodologies will be discovered.

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REFFERNCES-

1. Donaldson K, StoneV. Nano science fact versus fiction. ACM. 2004:113.

2. Ciaran H, Antonio A, Joseph JV, Hitendra RH Patel. Nano- and microrobotics: how far is the reality. J Expert Review of Anticancer Therapy.2008;12: 1891–97.

3. Jhaveri HM, Balaji PR. Nanotechnology: The future of dentistry. J Indian ProsthodontSoc 2005;5:15-7

4. https://en.wikipedia.org/wiki/Nanorobotics.

5. Vaughn JR. Over the Horizon: Potential Impact of Emerging Trends in Information and Communication Technology on Disability Policy and Practice. National Council on Disability, Washington DC. 2006:1–55.

6. MokhoffN. Education Overhaul Urged for Nanotech Revolution. EE Times Feb. 2003.

7. Cavalcanti A.Assembly Automation with Evolutionary Nano robots and Sensor-Based Control applied to Nano medicine. IEEE Transactions on Nanotechnology. 1992; 2 :82-7.

8. Brindle JA. Tactical military communications. IEEE Common. Mag. 1992;30 :62–72.

9. Couvrer P, Vauthier C. Nanotechnology: intelligent design to treat complex disease. Pharm. Res.2006;23 :1417–50.

10. Scheufele DA, Lewenstein BV,The Public and Nanotechnology: How Citizens Make Sense of Emerging Technologies. J. Nanoparticle Res . 2005; 7: 659–67.

11. Wong PC, Wong KK, Foote H. Organic data memory using the DNA approach. Communications of the ACM. 2003;46 : 95–8.

12. Seeman NC. From genes to machines: DNA nanomechanical devices. Trends in Biochemical Sciences. 2005; 30 : 119–25.

13. Tarakanov AO, Goncharova LB, Tarakanov YA. Carbon nanotubes towards medicinal biochips. Wiley Interdisciplinary Reviews: Nanomedicine and Nanobiotechnology. 2009;2: 1–10.

14. Ignatyev M.B. Necessary and sufficient conditions of nanorobot synthesis. Doklady Mathematics. 2010;82 : 671–75.

15. Shafagh R,Vastesson A, Guo W,Wijngaart VD, Wouter, HaraldssonT. E-Beam Nanostructuring and Direct click Bio functionalization of Thiol-EneResist.ACS Nano.2018;12:9940-46.

16. SharmaR. Photodynamic Therapy of Alzheimer's Disease Using IntrathecalNanorobot Drug Delivery of Curcuma Longa for Enhanced Bioavailability. JSRR.2013; 2: 206-27.

17. Titus L S. Nanodentistry fact or fiction. JADA. 2000 ; 131 :1567 -68.

18. Requicha AAG. Nanorobots NEMS and Nanoassembly. Proc. IEEE.2003; 91: 1922 – 33.

19. Cavalcanti A, Shirinzadeh B, FreitasJr,Kratky RA. Medical Nano robot architecture based on Nano bioelectronics. Recent Pat. Nanotech Bentham Science.2007; 1:1–10.

20. Kumar MNVR. Nano and Micro particles as Controlled Drug Delivery Devices. JPPS.2000; 3:234-58.

21. Shetty NJ,Swati P, DavidK. Nanorobots: Future in dentistry.Saudi Dent J.2013 ; 25: 49–52.

22. Frietas R A. Nanodentistry. JADA. 2000; 131: 1559 – 69.

23. Devasena UR, Brindha DP, Thiruchelvi R. A Review on DNA Nanobots – ANew Technique for Cancer Treatment. AJPCR. 2018;11: 61-64.

24. Ksy H, RaizadayA, Sivadasu P, Uniyal S,HemanthkumarS. Cancer Nanotechnology:Nanoparticulate Drug Delivery for the Treatementof Cancer. Int J Pharm Pharm Sci. 2014; 7: 40-6.

25. Janda E, Nevolo M, Lehmann K, Downward J, Beug H, Grieco M. Raf plus TGFBeta-Dependent EMT is Initiated by Endocytosis and Lysosomal Degradation of E-Cadherin. Oncogene 2006; 25: 7117-30.

26. Khulbe P. Nanorobots: A Review. IJPSR.2014;7: 2164-73.

27. Mali S. Nanotechnology for Surgeons.Indian J Surg.2013; 75: 485–92.

28. Modi DP, Patel VP, Patel RB, Patel JN, Bhavin V, Ragin B, Shah R. Nanorobots: The Emerging tools in Medicinal. IJDDR.2013; 5:105.

29. Murphy D, Challacombe B, Nedas T, Elhage O, Althoefer K, SeneviratneL,Dasgupta P. Equipment and technology in robotics. Arch.Esp.Urol. 2006;4: 349–54.

30. Roue CC, McNeil JS. Nano robot Pioneer Reveal Status of Simulator, Stem Cell Work. Nano Biotech News. 2004 ; 2: 4-5.

31. Ito T, Ikeda U. Inflammatory cytokines and cardiovascular disease. Current Drug Targets Inflammation and Allergy. 2003; 3: 257-65.

32. Cavalcanti A, Rosen L, Kretly LC, Rosenfeld M, Einav S.Nanorobotic Challenges In Biomedical Applications, Design and Control. IEEE ICECS Int'l Conf. on Electronics, Circuits and Systems. 2004.

33. Kube CR, Zhang H. Task Modelling in Collective Robotics. Autonomous Robots.1997; 1:53-72.

34. Whitcomb LL. Underwater Robotics: Out of the Research Laboratory and into the Field. IEEE Int'l Conf. on Robotics and Automation. 2002;709-16.

35. Wang J. Can Man-Made Nanomachines Compete with Nature Biomotors?. ACS Nano 2009; 1:4–9.

36. Regan BC, Zettl AK, Aloni S. Nanocrystal Powered Nanomotor. US Paten.t .2011; 7:863-798.

37. Venkatesan M, Jolad B, Emerging Trends in Robotics and Communication Technologies (INTERACT), International Conference on: IEEE, 2010; 258-64.

38. FreitasJr,Robert A, J Evol Technol. 2005; 14: 1-52.

39. FreitasJr Robert A. Bio-Inspired and Nanoscale Integrated Computing. 2009; 1: 391.

40. Powar PV. Development Status in The Meadow Of Nanostructure Magnetic Drug Delivery System And Its Promising Applications. IntJPharm Pharmsci. 2017; 9: 10-17

41. Patil M, Mehta DS, Guvva S. Journal of Indian Society of Periodontology. 2008; 12: 34.

42. ParmarDR,Soni JP, Patel AD,Sen DJ. Nanorobotics in Advances in Pharmaceutical Sciences. IJDDR. 2010; 2: 247-56.

43. Gupta J.Nanotechnology applications in medicine and dentistry JICD.2011; 2:81–8.

44. Saadeh Y, Vyas D. Nanorobotic Applications in Medicine: Current Proposals and Designs. Am J Robot Surg.2014; 1: 4-11.

45. SahaM. Nanomedicine: Promising Tiny Machine For The Healthcare In Future – A Review. Oman Med J. 2009; 4: 242-47.

46. SupingL, Jiang Q, Shaoli L, Yinlong Z, YanhuaT, Chen S, et.al.A DNA nanorobot functions as a cancer therapeutic in response to a molecular trigger in vivo .Nature Biotechnology. 2018 ;36: 258–64.

47. Abhilash M. Potential Applications of Nanoparticles.Int J Pharm Bio Sci .2010;1.

48. Robert AF. Current Status of Nanomedicine and Medical Nanorobotics. J.Comput.Theor.Nanosci. 2005;2:1-25.

49. Kroeker KL. Medical Nanobots .Communications of the ACM. 2009; 52: 18-19

50. Baheti MJ, Toshniwal NG. Nanotechnology: A Boon to Dentistry. J Dent Sci oral Rehab.2014;2:229-232.

51. Suresh M, ArumugamK,BalasubramaniamA,RadhakrishnanM,KalyaniRS,GurubaranNV. Nanorobots – A Small Wonder. Biosci. Biotech. Res. Asia.2016;13: 2131-34

52. Requicha AAG, Baur C, Bugacov A, Gazen BC, Koel B, Madhukar A, Ramachandran TR, Resch R, Will P. Nanorobotic assembly of two-dimensional structures. In: Proceedings of the IEEE international conference on robotics and automation, Leuven, Belgium, May 1998; 3368–74.

53. Mitra M. Medical Nanobot for cell and tissue repair. Int Rob Auto J. 2017;6: 218-22.