ISSN 0974-3618 (Print) **www.rjptonline.org**
0974-360X (Online)

REVIEW ARTICLE

Nanobots in Today's World

R. Thiruchelvi*, Eesani Sikdar, Aryaman Das, K. Rajakumari
Department of Bio-Engineering, School of Engineering, Vels Institute of Science, Technology and Advanced Studies, Pallavaram, Chennai– 600 117, Tamil Nadu, India.
*Corresponding Author E-mail: **thiruchelvi.se@velsuniv.ac.in**

ABSTRACT:
Nanobots are the recent and may be the future technology for many fields. The health care industry of today is focusing on developing minimally invasive techniques for diagnosis, as well as treatment of ailments. They are microscopic in nature and are used for various research purpose. It is used for medical as well an industrial purpose. some nanobots are used as a microscopic in surgical fields. This kind of microscopes is used to arrange the atoms. it is used in MRI where light is passed precisely through the concern region to heat it at 131°F which destroys the concern cells. In industrial purpose precisely it is used in oil industries. It is used in nanoparticles to produce light more efficiently. They are used in the manufacture of small processors and chips and in computers circuits.it helps to bridge the technological gaps between physics, chemistry and biology in nanoscale.

KEYWORDS: Nanobots, health industry, MRI, microscopes, processors, chips.

INTRODUCTION:
Nanobots have in the past been a fixture of science fiction writing and illustration, and such ideas are now also appearing in scientific research. But, as Chris Toomey explains, practical nanobots are different from their science fiction counterparts. Science fiction writers produced stories of miniaturized machines long before the prefix 'Nano' was crafted to mean a billionth of a metre (or a litre, or a gram, and so on). The most famous of these machines was the Proteus, which appeared in the 1966 film Fantastic Voyage. In the film, a small submarine and its crew were temporarily miniaturized for the purpose of saving the life of an important scientist by entering his blood stream and destroying a clot in his brain. This was good science fiction, especially the urgency for the crew to exit the patient's body before they returned to normal size. Three kinds of nanobots (abbreviated from 'Nano-robots') populated latter-day science fiction illustration.

Received on 23.04.2019 Modified on 20.07.2019
Accepted on 26.09.2019
Research J. Pharm. and Tech 2020; 13(4):2031-2037.
DOI: 10.5958/0974-360X.2020.00366.2

The second was a group of submarines like vessels that would locate viruses and other pathogens, and then destroy them with lethal rays. The third was the Nano louse, which had mechanical claws to seize a red blood cell and insert a needle into it.[1,2,3,4]

Fig: 1

TYPES OF NANOBOTS:
Nanoparticle are the compounds that enhance MRI scanning and ultrasound results in biomedical applications. These particles typically contain metals whose properties are dramatically altered at the Nano-scale. Gold "Nano shells" are useful in the fight against cancer, particularly soft-tissue tumours, because of their ability to absorb radiation at certain wavelengths. Once the Nano shells enter tumour cells and radiation treatment is applied, they absorb the energy and heat up enough to kill the cancer cells. Positively-charged silver nanoparticles are used for its detection by adsorbing the

single standard DNA. In the case of cancer therapies, drug delivery properties are making together with imaging technologies and other new advances tools, so that cancer cells can be located visually with under process treatment. Once the drug is delivered, if the nanoparticle is also an imaging agent, doctors can follow its progress and the distribution of the cancer cell is known. Such specific targeting and detection will aid in treating late-phase metastasized cancers and hard-to-reach tumours and give indications of the spread of those and other diseases. It also extends the life of some drugs that have been found in a nanoparticle than when it is directly injected to the tumour, since often drugs that have been injected into a tumour diffuse away before effectively killing the tumour cells. Molecular nanotechnology refers to the three-dimensional positional control of molecular structure to create materials and devices to molecule. More than just molecular medicine, nanomedicine which maintain and improve the human health at the molecular scale. [5,6,7,8]

NANOMEDICINES:

Nanotechnology has become a new advent of medicine (Nano-medicine). The use of nanotechnology in medicine offers some many possibilities. Some techniques are at various stages of testing, or actually being used today while others are only imagined. There are two main approaches are used in nanotechnology. Second is "top-down" approach where they are made by removing existing material from larger entities. Nanotechnology in medicine involves longer ranges research that involves the use of manufactured Nano-robots to make repairs at the cellular level as well as applications of nanoparticles are currently under development. This highly performed activity reduces costs and human suffering. A targeted or personalized medicine reduces treatment expenses and the drug consumption resulting in an overall societal benefit. Nanotechnology can help to repair or to reproduce damaged tissue. This process which makes use of artificially stimulated cell proliferation by using suitable nanomaterial-based scaffolds and growth factors is called as "tissue engineering". Tissue engineering might replace today's conventional treatments, e.g. transplantation of organs or artificial implants. There are four entry routes for nanoparticles into the body: they can be absorbed through skin, inhaled, swallowed or be deliberately injected during medical procedures. Once within the body they are highly mobile in some instances can even cross the blood-brain barrier.[9,10,11,12]

APPLICATION OF NANOBOTS IN MEDICINES:

For the sake of increasing knowledge of the human body, etc. Nanoparticles are taking over the world of biomedicines.[13, 14]

Uses in Drugs and Medicine Nanotechnology can make the body parts more effective and less harmful to the other parts of the body by delivering medicines or drugs to those specific parts. Anti-cancer gold nanoparticles have been found very effective. Gold "Nano shells" are useful to fight cancer because of their ability to absorb radiation at certain wavelengths. Once the Nano shells enter tumour cells and radiation treatment is applied, they absorb the energy and heat up enough to kill the cancer cells. Not only gold but other elements can also be used [15,16].

Uses in Surgery With nanotechnology, very small surgical instruments and robots can be made to perform microsurgeries on any part of the body. These instruments would be precise and accurate, targeting only the area where surgery should be done instead of damaging a large amount of the body.

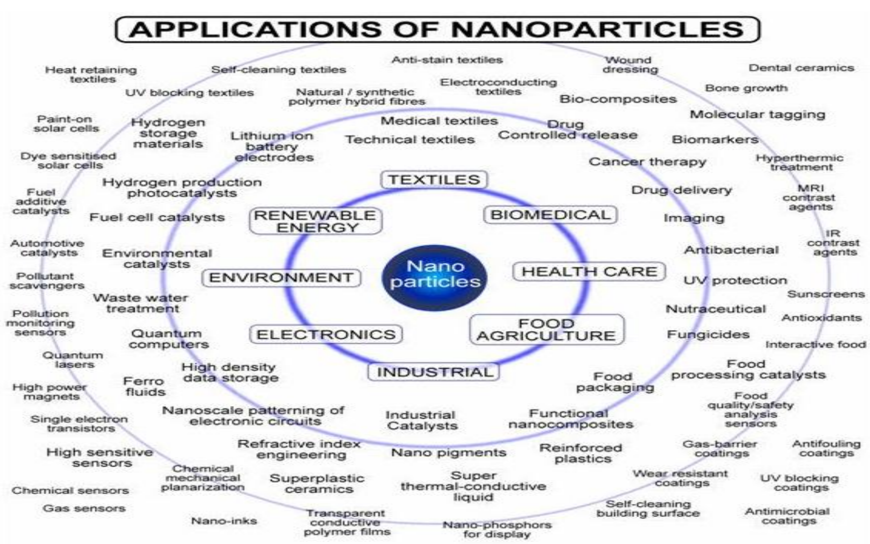

Fig: 2

Visualization of surgery can also be improved. Computers can be used to control the Nano-sized surgical instruments instead of surgeon holding the instrument. Instruments such as “Nano cameras” can provide close up visualization of the surgery. There is less chance of any mistakes or faults. Surgery could also be done on tissue, genetic and cellular levels.[17,118]

Nano-robotics although having many applications in other areas, have the most useful and variety of uses in medical fields. To perform treatment in the cellular level future medical nanotechnology expected to employ nanorobots injected into the patient. The workings of cells, bacteria, viruses etc can be better explored. The causes of relatively new diseases can be found and prevented. [19,20]

Restore vision Genome sequencing can be made much easily. Biological causes of mental diseases can be identified and monitored. Simple curiosity can be answered. Tissue engineering could also be done using Nano-materials. [21,22]

Tissue engineering based scaffolds and growth factors makes use of artificially stimulated cell proliferation by using suitable nanomaterial-. Life extension in humans and other animals can be achieved by advanced in tissue engineering. [23,24]

THE END OF AGING AND DISEASES:
The result of these technological advances will be the effective end of aging as well as the reversal of one’s current biological age to any new age that is desired. These procedures are anticipated to become commonplace as the technology evolves, a few decades hence. You could remain virtually constantly your ideal biological age With routine annual checkups/ repairs, and the occasional major tune-up., However most deaths will likely become accidental, rather than “natural” but People will still die at some point., A life expectancy of at least one thousand years is expected based on projected rates of accidental death and suicide - if we don’t annihilate ourselves in the interim. Perhaps the most significant danger in curing aging is in the intellectual and cultural stagnation of humankind that may result if the current generation were stopped in time. Aging and Disease start from the molecules in our tissues finally into disorder, first destroying health, and gradually taking life itself. Nanotechnology will give us numerous novel approaches and undo the disastrous results of the ravages of time and to repair our aging bodies. The applications seen in the Nano age offer the first promising hope of a science-based fountain of youth. Radical life (and health) extension will become commonplace. [25,26,27]

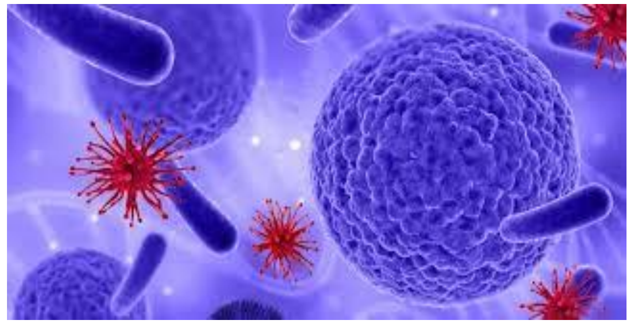

Fig: 3

APPLICATIONS OF NANOBOTS IN NANOMEDICINES:
In 1966 inside a scientist’s body to remove a clot in the brain. But scientists in twenty first century have achieved some success to transform that fiction into reality. Nanobots have wide applications in nanomedicine and some of its features have been used for diagnostic and therapeutic purpose.[28,29,30]

A professor from Ilan University announced treatment of cancer with nanomedicine. He said DNA nanobots can identify different kinds of cancer tumours in humans and believes that within very short time span nanobots could repair spinal cord damages and could cure cancer. Smart engineered nanobots have ability to deliver medicaments in controlled release form apart from detecting cancer. Some Other nanobot which are capable of destroying microbiological pathogens inside humans. Called “Microbivores” “Colonocytes” have ability to heal by making fibre mesh upon command at the site of wound. Artificial micromotors have great potential to operate locally in-vivo for diverse medical applications. [31,32]

NANOROBOTS AND NANODEVICES:
The Primary medical applications of reciprocates would include, lung disorders, enhancement of cardiovascular/neurovascular procedures, tumour therapies and diagnostics, prevention of asphyxia, artificial breathing, and a variety of sports, veterinary and battlefield transfusable blood substitution; partial treatment for anaemia. Microbivores are 1000 times faster acting than either unaided natural assisted biologic phagocytic defences. Medical “nanorobots” may also be able to intervene at the cellular level, performing in-vivo cryosurgery. The most likely site of pathologic function in the cell is the nucleus – more specifically, the chromosomes. In one simple cryosurgical procedure called “chromosome replacement therapy”, a “nanorobot” controlled by a physician would extract existing chromosomes from a particular diseased cell and insert new ones in their place, in that same cell. Inherited defective genes could be replaced with non defective base-pair sequences, permanently curing a

genetic disease if the patient chooses. Engineered bacterial “biobots” are designed to produce useful vitamins, hormones, enzymes or cytokines in which a patient’s body was deficient to metabolize harmful substances such as poisons toxins etc into harmless end products. [33, 34]

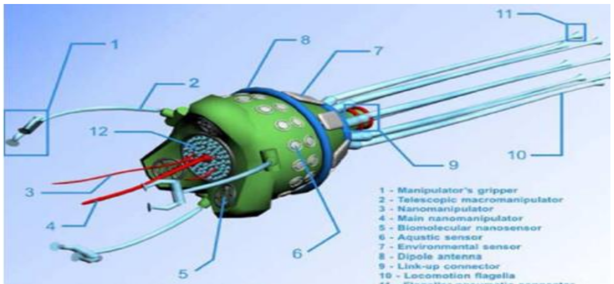

Fig: 4

CARDIOLOGY:

Minimally invasive treatments for heart disease, diabetes and other diseases are a desirable goal for scientists, and there is hope for it, because of the use of nanotechnology. Of those steps, the last is the most challenging. it is the creation of muscle-powered nanoparticles that have the ability to transfer information into different cells which gives the potential in the replacing of the lost biological function of many damaged tissues such as sinoatrial node. This effect can lead to treatment of diseases which otherwise would be fatal or difficult to cure for human beings and Coronary Artery disease (CAD), by improving the biocompatibility of intracoronary stents and by regulating the main limit factors for Percutaneous Transluminal Coronary Angioplasty (PTCA) at a molecular level via nanoparticles.[35,36]

Many monoclonal antibodies, peptides and carbohydrates for non-invasive targeting of atherosclerotic lesions, myocardial necrosis, brain infarction and various tumours can be used for their detection with single-stranded DNA.

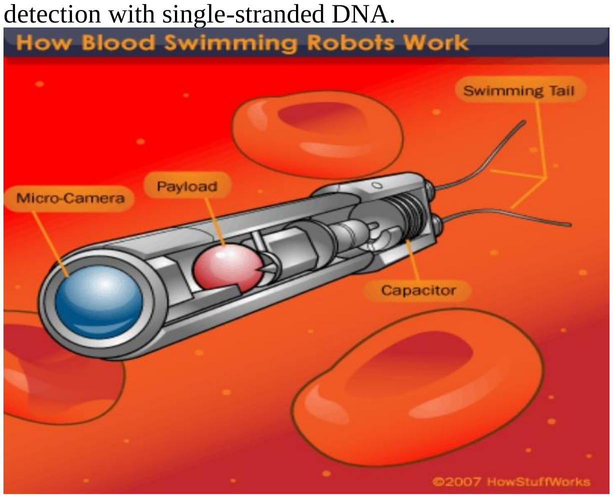

Fig: 5

If a single nucleotide alteration occurs, the association between the carbon nanotube and the complementary DNA strand will be changed, resulting in the detection of single-nucleotide polymorphisms (SNPs). SNPs are the special sites in the human genome where individual’s DNA sequence are being single base. These slight variations in DNA sequences can affect the person which may develop a disease and even in the worst condition in response to drug segments. [37,38]

AGAINST CANCER:

Nanotechnology may have an impact on the key challenges in cancer revolutions in genomics, proteomics and cell bio1ogy. Recently, there is a lot of research going on to design novel nanodevices capable of detecting cancer at its earliest stages, pinpointing its location within the human body and delivering chemotherapeutic drugs against malignant cells. Tumour diagnostics and prevention is the best cure for cancer, but failing that, early detection will greatly increase survival rates with the reasonable assumption that an in-situ tumour will be easier to remove[39,40].

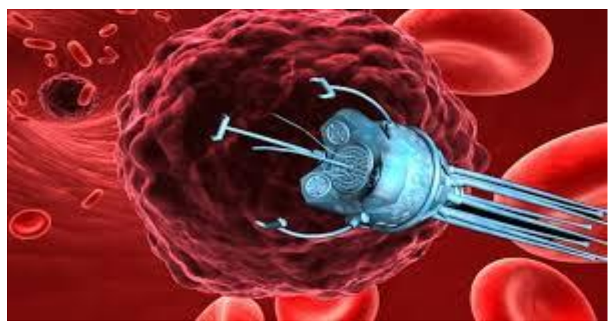

Fig:6

Nanoparticle contrast agents are being developed for tumour detection purposes. Labelled and non-labelled nanoparticles are already being tested as imaging agents in diagnostic procedures such as nuclear magnetic redo-nuance imaging. Moreover, quantum dots being the nanoscale crystals of a semiconductor material such as cadmium selenide, can be used to measure levels of cancer markers such as breast cancer marker Her-2, actin, microfibril proteins and nuclear antigens. Tumour treatment can be succeeded with nanoscale devices (such as dendrimers, silica-coated micelles, ceramic nanoparticles, liposomes)[41,42].

Nano particles may be used, when inhaled, to stimulate an immune response to fight respiratory viruses. Quantum Dots (dots) may be used in the future for locating cancer tumours in patients and in near tern for performing diagnostic tests in samples.

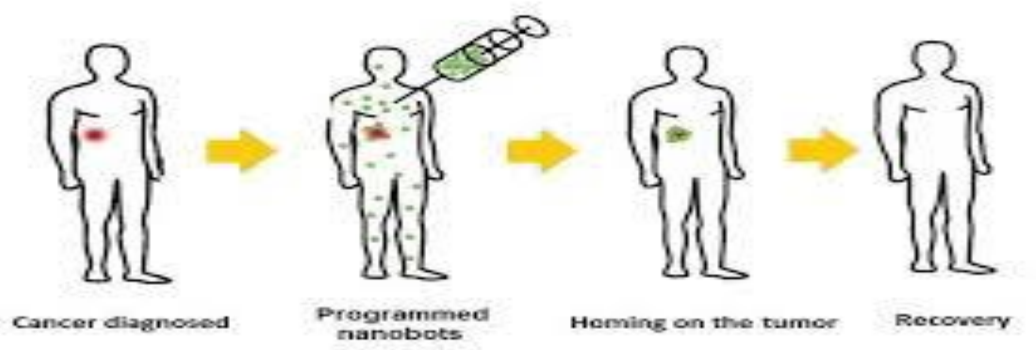

Fig: 7

Nanobots used in cell and tissue repairing:
INTRODUCTION:

Nanobot's is also called as nanite whose dimensions are measured in nanometres and it is equal or smaller than one micrometer, or to manipulate components on the range of 1 to 1000 nm in size which is a mechanical/electromechanical device. Nanobots are so small that they actually interact on the same level as bacteria and viruses do, and so they are capable of building with the very particles of our bodies: atoms and molecules. Nanobot can be merged with all types of tools such as camera (to see and to furnish more extensive information about the human body), Nano laser and Nano chemical (to clean infected area). Apart from this, nanobots can be controlled internally and externally in order to perform a lot of useful tasks. Nanobot can perform a variety of same functions, from disposing away dead cells/tissues at the place of a wound and helping in again growing tissue so that it heals quickly and cleanly without leaving a nasty scar. It can also help with festering wounds, which could easily be cleared by medical nanobot.[43,44]

WORKING PRINCIPLE:

Grammid medical nanobots are introduced inside the infected patient body and nanobots automatically detect the infected/ damaged tissue, all the nanobots move to the infected tissue and use laser to remove infected/dead cells attached to the infected tissue. As soon as all the dead cells are removed and infected area is cleaned then nanobot start repairing the tissue (similar to what WBC does inside our body). All the work such as removing the dead cells, cleaning the infected area and repairing the cells can be or cannot be done by single nanobot. Thus, we need multiple nanobot. The whole process is so fast that patient can be healed as quickly as few hours for minor wounds and major wounds it may include all the drawbacks of using nanobots in the human body. A person should not increase the maximum prescribed amount of nanobots in his or her body. The reason being increasing nanobots in his or her body will also increase the toxicity in the blood and it may adverse the health of the effected patient. Although nanobots can be programmed to maintain the maximum amount. [45]

MAJOR COMPONENTS:

i. **Molecular sorting rotor:** It is made of carbon nanotube. It is a class of Nano-mechanical device capable of Depicts that multiple Nanobot heal the damaged tissues.
a. A damaged cell/tissue is detected.
b. The selectively binding (or releasing) molecules from/ to solution, and of transporting these bound molecules against significant concentration gradients
ii. **Propeller:** It is used for nanobots to drive forward against the blood stream.
iii. **Nano camera:** Nanobot may include a miniature camera at the size of nanometre
iv. **Lasers:** These lasers could burn the harmful material like arterial plaque, blood clots or cancer cells.
v. **Fin:** A fin is a surface used for stability and/or to produce lift and thrust or to steer while traveling in water, air, or other fluid media. It is built-in along with the propellers used to propel the device).[46]

Applications, advantages and disadvantages:
Applications:

The following are the sample list of applications to start with but there are many other useful tasks that nanobots can perform that are not listed here.

i Removing Kidney Stones and Liver Stones.
ii To cure skin diseases.
iii Neuron replacement.
iv It would prevent heart attack, kill cancer cells etc.
v It kills the bacteria and viruses which are feeding from the immune system
vi It can be used as mouthwash to do all brushing and flossing.
vii Smart anti-cancer Therapeutics.
viii Parasite removal.
ix Targeted drug delivery.
x In treatment of Arteriosclerosis's. [47]

Advantages:

There are many advantages of nanobots and one of the major advantages that we want to point it out is that patient's whole tissue can repaired in few simple steps. Below are the some of the advantage.

a. Nanobot may help in the function at the atomic and molecular level to build many advance devices, machines or circuits known as molecular manufacturing for different industries.
b. It may produce different copies of themselves to replace the damage tissue, and this process called self-replication
c. Individual units require only a tiny amount of energy to operate
d. The major advantage of nanobots is thought to be their durability, in theory, they can remain operational for years, decades or centuries. [48]

Disadvantages:

One of the major disadvantagesof the nanobots are pointed in a list

It increases the toxicity in the blood stream and may affect the health of the infected patient.

Below are the some of the disadvantages.

a. Expensive technology.
b. Complicate design.
c. Initial design cost is very high.
d. Hard to program.
e. Limited external control mechanisms.
f. May affect human health by introducing toxicity in blood.
e. SWOT (Strength Weakness Opportunities Threat) analysis

I. Strength: Since it is a new method many undergoing experimentations are running united states specially work on it to developed the nanobots technologies.

ii. Weakness: Since it is new way of treatment it is under developed it requires many funding and instrumentation for developed the technologies, it also requires the raw material and the idea of the future product of this technology.

iii. Opportunity: In United States Health Care is on the highest priority and there is a lot more to not only improve the Health Care but also need to add more and more technologies for betterment of mankind.

iv. Threats: There are many threats that are required to overcome since it has to be developed, tested, deployed and pre-production testing has to be completed which itself is considerable.

CONCLUSION:

From the above we conclude that nanobots are helpful in various medicinal purposes. The first and most important of them is tissues repair. It is widely used in the repairing of dead and worn out tissues. Here we discuss about the various therapeutically and diagnostics uses of the nanobots. We have seen a wide range of application of nanobots in various fields. For examples in cardio, ageing, cancer, medicines, etc and some others fields are we have discussed are haematologies, cancer detection and biohazard defence. On the other hand, we have discussed some disadvantages of the nanobots in various fields. [49]

ACKNOWLEDGMENT:

The Authors are thankful to the Assistant professor and management of Vels Institute of Science, Technology and Advanced Studies for providing a facility to carry out this work.

CONFLICT OF INTERESTS:

There is no conflict of interests.

REFERENCES:

1. Nerlich, B. Science as Culture 17, 269–292 (2008)
2. Lynn, S. in Encyclopaedia of Nanoscience and Society Vol. 2 (ed. Guston, D.) 700–701 (Sage, 2010).
3. AkhileshLatakia (ed) (2004). The Handbook of Nanotechnology. Nanometre Structures: Theory, Modelling, and Simulation. SPIE Press, Bellingham, WA, USA. ISBN 0-8194-5186-Biology and Medicine 2005; 1:351
4. Bonnemain. "Superparamagnetic agents in magnetic resonance imaging: physiochemical characteristics and clinical applications – a review" J Drug Target 1998; 6:167-174.
5. Daniel J. Shanefield (1996). Organic Additives and Ceramic Processing. Kluwer Academic Publishers. ISBN 0-7923-9765 7Elwing H, "Protein absorption and ellipsometry in biomaterial research", Biomaterials 1998; 19:397; Garcia-Caurel Å, Nguyen J, Schwartz L, Drévillon B, "Application of FTIR ellipsometry to detect and classify microorganisms", Thin Solid Films 2004; 455:722; "Moving ellipsometry from materials to medicine". III-Vs Review 2004; 17:4.
6. Fei Wang andAkhilesh Lakhtakia (eds) (2006). Selected Papers on Nanotechnology — Theory and Modelling (Milestone Volume 182). SPIE Press, Bellingham, WA, USA. ISBN 0-8194-6354-X[6].
7. Going beyond drug-eluting stents". Drug Discovery Today: Disease Mechanisms/Cardiovascular diseases 2005; 2: IIIc
8. http://www.ncbi.nlm.nih.gov/pmc/issues/178370 - A link to an official government nanotechnology journal published by NIH (National Institute of Health) – "International Journal of Nanomedicine". The articles are all open-source and updated with the newest developments in biomedical nanotechnology.
9. Hunt, Geoffrey and Mehta, Michael (eds) (2006). Nanotechnology: Risk Ethics, and Law. Earthscan, London.
10. Jong WH de, Roszak B., Geertsma R.E., "Nanotechnology in medical applications: possible risks for human health", RIVMreport 265001002, 2005. RIVM, National Institute for Public Health and the Environment, Belhaven, The Netherlands, 2005.
11. Kane JP, Aguilera BE. "Novel genetic markers for structural coronary artery disease, myocardial infarction, and familial combined hyperlipidaemia: candidate and genome scans of functional SNPs", Atherosclerosis XIII. Proceedings of the 13th International Atherosclerosis Symposium 2004; 1262:309- 312
12. Kawasaki ES, Player TA. "Nanotechnology, nanomedicine, and the development of new, effective therapies for cancer", Nanomedicine: Nanotechnology, Biology, and Medicine 2005;1:101–109
13. Logothetidis S, Gioti M, Louisiana S, Fotiadis S,

"Hemocompatibility studies on carbon-based thin films by ellipsometry". Thin Solid Films 2004; 482:126
14. Nanomedicine; An ESF – European Medical Research Councils (EMRC) Forward Look report 2005, (www.nanoforum.org)
15. Nanomedicine: Nanotechnology, Biology, and Medicine 2005; 1:326
16. Robert A. Freitas Jr, JD, "What is nanomedicine?", Nanomedicine: Nanotechnology, Biology, and Medicine 2005; 1:2
17. Rocco M C. "Nanotechnology: convergence with modern biology and medicine". Current Opinion in Biotechnology 2003
18. Roszak B, Jong WH de, Geertsma RE. "Nanotechnology for medical applications: state-of-the-art in materials and devices", RIVM report 265001001, 2005. RIVM, National Institute for Public Health and the Environment, Bilthoven, The Netherlands, 2005
19. Silva G. A., "Introduction to nanotechnology and its applications to medicine". Surg Neurol 2004; 61:216 19. Service R F, "Nanotechnology Takes Aim at Cancer", Science 2005; 310, No.5751, p.1132; M.M. Stevens, J.H. George, "Exploring and Engineering the Cell Surface Interface". Science 2005; 310, No.5751, 1135 33. www.euronanotechnews.com
20. Tachung C, Yih PE, Wie C. "Nanomedicine in cancer treatment". Nanomedicine: Nanotechnology, Biology, and Medicine 2005; 1:191-92
21. Vladimir P, Zharov DSc, Jin-Woo Kim, et al. "Self-assembling nanoclusters in living systems: application for integrated photothermal Nano diagnostics and Nano therapy".
22. Zandonella C. "The tiny toolkit". Nature 2003; 423:10-12 24. Brigger É, Dubernet C, Couvreur P. "Nanoparticles in cancer therapy and diagnosis". Advanced Drug Delivery Reviews 2002; 54:631-651
23. Introduction to Nanotechnology. Nano Gloss.
24. Shalini (2014) Nanobots as therapeutic Devices. Slide Share.
25. Design Architecture of Nanobot. Smart DNA mounts.
26. Rigivendra KumarVardhan (2015) Nano Robotics. Slide Share.
27. Manjunath Apoorva, Vijay Kishore (2014) The Promising Future in Medicine: Nan robots. Science and education 2(2): 42-47.
28. Jerrica Dujmovic (2016) Nanobot are waiting in the wings to cure cancer and clean up ocean pollution.
29. Yog (2012) Power Sources of nanorobotics.
30. Thomas E, Mallouk and Ayusman Sen (2009) Powering Nanorobots. Nano Technology p-1.6
31. Inbal Wiesel, Noa Agmon and Gal A. Kaminka A Compiler for Programming Molecular Robots. Bar Ilan University, Israel, p. 1-2.
32. Inbal Wiesel-Kaph, Gal A Kaminka, Guy Hochman, Noa Agmon, Idol Bachelet (2016) Rule-Based Programming of Molecular. Proceedings of the Twenty-Fifth International Joint Conference on Artificial Intelligence. Bar Ilan University, Israel, p. 1-8.
33. Anita, E.- "Nanorobots "GRA - global research analysis Nov2012 vol.1 issue 5 issn 2277-8160 pg45-48
34. Cavalcanti, A. Rosen, L. Kretly, L.C.Rosenfield. Einav, S. - "Nanorobotic challenges in biomedical 48 I.J.E.M.S., VOL.5 (1) 2014:44-49 ISSN 2229-600X Nanobots: The future of medicine 49 applications, design and control" IEEE ICECS Int'l conf. on electronics, circuits and systems Tel-Aviv, Israel, December 2004
35. Dreyfus, R. Baury, J. Roper, M.L. Fermigiev, M. Stone, H.A Babette, J. "Microscopic artificial swimmers", Nature, vol. 437, 862, (2005).
36. Freitas Jr., R.A-"Current status of nanomedicine and medical nanorobotics", Computational and theoretical nanoscience vol.2, 1–25, 2005
37. Nelson, B.J-"Micro robotics in medicine", ETH Zurich http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.98.994andrep=rep1andtype=pdf
38. Nelson, B.J Kahikatoas, I.K Abbott. - "Microrobots for minimally invasive medicine" -Anna. Rev. Biomed. Eng. 2010.12. By Eigensystem Technosphere Hochschule, Zurich
39. Requite, A.G"Nanorobots, NEMS, and Nano assembly" proceedings of the IEEE, vol. 91, no. 11, November 2003 invited paper
40. Sharma, N. N Mittal, R.K. "Nanorobot movement: challenges and biologically inspired solutions" International Journal on Smart sensing and Intelligent Systems, vol. 1, no. 1, march 2008
41. Shirai, Y. OsgoodZhao K KellyTour "Directional control in thermally driven single-molecule nanocaps", Nanolet., vol. 5, 2330- 2334, (2005). Wikipedia: Quantum computer http://en.wikipedia.org/wiki/quantum_computer
42. Wikipedia: Magneto tactic bacteria
43. http://en.wikipedia.org/wiki/Magnetotactic_bacteria.
44. Loach, A. Yearbook of Nanotechnology in Society Vol. 1 (eds Fischer, E. et al.) 123–142 (Springer, 2008).
45. Toomey, C. and Cobb, M. Leonardo 45, 461–465 (2012).
46. Douglas, S., Bachelet, I. and Church, G. Science 335, 831–834 (2012).
47. http://www.whitehouse.gov/the-press-office/2013/04/02/ fact-sheet-brain-initiative
48. Markoff, J. New York Times D1, D6 (26 February 2013). 8. Service, R. Science 330, 314–315 (2010).
49. R. Seigneuric and all: From Nanotechnology to Nanomedicine: Applications to Cancer Research; Current Molecular Medicine 2010,10, 640-652