Nanorobotics

Chapter · January 2010

DOI: 10.1007/978-3-642-02525-9_46

2 authors:

Brad Nelson
ETH Zurich

Lixin Dong
City University of Hong Kong

DHR International Journal Of Pharmaceutical Sciences (DHR-IJPS), Vol. 2, Issue 1, 2012
Available online *http://www.doublehelixresearch.com/DHRIJPS*

Original Article

Nanorobotics

Deepak N.Kapoor*, ArvindSingh[1], Sushila Singh[1]

Oniosome Research Centre (ORC), Oniosome Healthcare Pvt. Ltd., Mohali – 160071, INDIA
[1]National Dairy Research Institute, Karnal, INDIA

Abstract

Nanorobotics is an emerging, advanced and multidisciplinary field that calls for scientific and technical expertise of medical, pharmaceutical, bio-medical, engineering as well as other applied and basic scientists. Nanorobots differ from macro-world robots, specifically in theirnano-sized constructs. Assembly and realization of nanorobotsdepend on the principles of molecular nanotechnology and mechanosynthetic chemistry. Practically, these systems are nanoelectromechanical devices that are capable to carry out pre-programmed functions in a reliable and accurate manner with the help of energy provided by a pre-installed nanomotor or nanomachine. Due to their small size and wide functional properties, nanorobots have createdexceptional prospects in medical, biomedical and pharmaceutical applications.Although, no technology is available to construct artificial nanorobots, it is now possible to create nanorobots by using biological means. The review presents a brief discussion on basic nanorobotics and its possible applications in medical, biomedical and pharmaceutical research.

Keywords

Nanotechnology; nanomedicine; nanomachines; nanomotors; bionanorobots; nanomechanics

Introduction

Nanorobots are programmable assemblies of nanometer scale components constructed by manipulating macro/micro devices or by self-assembly on pre-programmed templates or scaffolds [1]. Nanorobots are essentially nanoelectromechanical devices (NEMS). These nanorobotic devices are comparable to biological cells and organelles in size. The technology of design, fabrication, and programming of these nanorobotsis known as Nanorobotics [2, 3]. It is a multidisciplinary field requiring advanced level input from different areas of science and technology including, physics, chemistry, biology, medicine, pharmaceutical sciences, engineering, biotechnology and other biomedical sciences.

Richard Feynman, Nobel laureate and a scientist predicted nanomachines to be devices of the future [4]. The concept of medical nanodevices traveling in the human body was first viewed in the movie Fantastic Voyage (Twentieth Century Fox, winner of the 1966 Oscar for best visual effects). Since then, nanomechanics have become the matter of scientific or technical curiosity and debate for researchers. It is predicted that nanorobotics would deliver unprecedented results in medicine and drug delivery applications [5]. These systems would be useful for drug targeting, controlled drug release, tumor diagnosis, cellular as well as genetic repair in the biological system.

Following the publication trends, specifically in medical nanorobotics, it appears that there exist two schools of thought concerning the practical feasibility of nanorobots. Apart from the general view of the scientific community, which considers it theoretically acceptable but actually impractical, there exists a pool of scientists working in molecular nanotechnology and mechanosynthesis for nanorobotic applications. Eminent scientists including Feynman, Merkle, Drexler [6] and Freitas [7] have contributed significantly in the advancement of nanorobotic devices.

Molecular machines

Nanorobots need energy to carry out different manipulations such as propulsion, force, actuation, communication or any other activity in the biological system at nano-scale [8]. This energy can be generated by natural (biological) or artificial (chemical) entities known as molecular motors, which when perform at nano-scale are known as Nanomachines [9]. The natural molecular motors are present in a biological system and carry out important functions in the body at molecular or nano level. Most of these motors are composed of proteins or DNA. Scientists are studying these natural motors elaborately in order to use them as efficient and reliable motors for artificial nanorobots, e.g., Kinesin molecular motors [10], flagella motors [11], DNA Scissors [12] and DNA Tweezers [13, 14]. Similarly, chemical molecular motors are also being used as nanomachinesin artificial nanorobotics [15]. These machines are difficult to synthesize but are more robust than natural machines. Mostly, these machines are constructed from organic compounds such as Carbon, Nitrogen, and Hydrogen and can be controlled chemically, electrochemically or photochemically. Many chemical molecular machines are constructed using interlocked organic compounds known as Rotaxanes and Catananes [16].

Nanofabrication and assembly

Currently, scientists have succeeded to develop only biological nanorobotic systems, whereas, artificial nanorobots are still a concept that is being explored aggressively. The key challenge in the development of these systems is their fabrication and assembly at nano-scale. Various techniques are being developed for nanomanipulation including scanning probe microscopy (SPM) and Atomic Force Microscopy (AFM) as a couple of promising methods for small-scale development of nanodevices [1, 2]. These techniques use micro cantilevers suitable for miniaturized manipulation and assembly. Self-assembly of nanostructures is emerging as another useful method [17]. It has been observed that nanoprobes or nanosensors would diversify the applications of nanorobots in the biomedical field. The key processes or components required for construction of nanorobots involve sensing, actuation, propulsion, control, communication, programming and coordination [1]. Until now, only primitive, artificial nanorobotshave been developed and much advanced versions are expected in the near future with the development novel technologies.

Medical and pharmaceutical applications

An ideal nanorobotic system is visualized as a self-assembling, self-replicating and self-repairing systems. Although, such an advanced artificial system may not be seen in the near future, it could be possible by using viral vectors or very small virus like particles (VSVLI) as carriers for drugs, diagnostic agents or other therapeutic biological material.

Several other hypothetical nanorobotic systems have been proposed for the treatment and diagnosis of various diseases and disorder. Table 1 shows nanorobotic systems proposed by Freitas, R.A.:

Table 1: Different Hypothetical Nanorobotic Systems

System	Application	References
Microbivores	Artificial mechanical white cells	[7]
Respirocytes	Artificial mechanical red cells	[7]
Dentifrobots	Dental nanorobots	[7]
Clottocytes	Artificial mechanical platelets	[18]
Pharmacytes	Nanorobotic pharmaceutical drug delivery device	[19]
Chromallocytes	Gene delivery, Chromosome Replacement Therapy (CRT)	[20]

Conclusion

Nanorobotics is an upcoming field interconnecting various areas of science and technology. The advantages and applications of nanorobots in medicine and engineering technologies outweigh the challenges and hurdles it presents during the development process. It is clearly seen from the examples of biological molecular motors and bionanorobotics that it is difficult but possible to develop such systems. The day may not be far when nanorobotics would enter into the nanomedicine world as a boon for those suffering from various difficult to treat conditions such as cancer and AIDS.

References

[1] A.A.G. Requicha, Nanorobots, NEMS and Nanoassembly.*Proceedings of the IEEE,*2003, 9, 1922-1926.

[2] N.A. Weir, D. P. Sierra, J. F. Jones,*A Review of Research in the Field of Nanorobotics*; Sandia National Laboratory, Sandia Corporation: Albuquerque, New Mexico, 2005.

[3] A. Ummat, A. Dubey, C. Mavroidis, In *CRC Handbook on Biomimetics: Mimicking and Inspiration of Biology*, ed. Y. Bar-Cohen., CRC Press, 2004.

[4] R. Feynman, There is plenty of room at the bottom. *Science,*1991, 254, 1300-1301.

[5] R.A. Freitas, *Nanomedicine, Volume I: Basic Capabilities*,Landes Bioscience: Georgetown, TX, 1999.

[6] K.E. Drexler, *Engines of Creation: The Coming Era of Nanotechnology*,1986.

[7] R.A. Freitas, Current status of nanomedicine and medical nanorobotics. *Journal of Computational and Theoretical Nanoscience,*2005, 2.1-25.

[8] K.E. Drexler, Molecular engineering: an approach to the development of general capabilities for molecular manipulation,*ProcNatlAcadSci USA,* 1981, 78, 5275-8.

[9] K.E. Drexler, *Nanosystems: Molecular Machinery, Manufacturing and Computation*. John Wiley & Sons: New York, 1992.

[10] S.M. Block, Kinesin, What Gives? *Cell,*1998, 93.5-8.

[11] R.M. Berry, J.P. Armitage, The bacterial flagella motor. *Advances In Microbial Physiology* 1999, 41, 291-337.

[12] J.C. Mitchell, B. Yurke, In *7th International Meeting on DNA-Based Computers, DNA7*, ed. S.N. Jonoska. Springer Verlag, Heidelberg: Tampa, FL, USA, 2002.

[13] B. Yurke, A.J. Turberfield, A.P. Mills, F.C. Simmel, J.L. Neumann, A DNA-Fuelled Molecular Machine Made of DNA. *Nature,*2000, 415, 62-65.

[14] A. Ummat, A. Dubey, G. Sharma, C. Mavroidis, in *Tissue Engineering and Artificial Organs (The Biomedical Engineering Handbook)*, ed. M. L. Yarmush, CRC Press, 2006.

[15] V.V. Balzani, A. Credi, F.M. Raymo, J.F. Stoddart, Artificial Molecular Machines,*AngewChem,*2000, 39, 3348-3391.

[16] J.P. Sauvage, C. Dietrich-Buchecker, *Molecular Catenanes, Rotaxanes and Knots*.Wiley-VCH: Weinheim, 1999.

[17] J. Dutta, H. Hofmann, in *Encyclopedia of Nanoscience and Nanotechnology*, ed. H.S. Nalwa, American Scientific Publishers: USA, 2003, vol. X, pp 1-23.

[18] R.A. Freitas,*Clottocytes: artificial mechanical platelets*; 41, Foresight Inc,2000.

[19] R.A. Freitas, Pharmacytes: an ideal vehicle for targeted drug delivery,*J NanosciNanotechnol*2006, 6, 2769-75.

[20] R.A. Freitas, The Ideal Gene Delivery Vector: Chromallocytes, Cell Repair Nanorobots for Chromosome Replacement Therapy,*The Journal of Evolution and Technology,*2007, 16, 1-97.