A Brief Review on Nanorobots

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Abstract

This paper proposes the overview of the nanobots. Nanorobots is the emerging technology field of developing machines which are of nanoscale. The major applications of nanorobots are in medical field. They are used in medical field for treating cancer, checking blood contents, diagnoses and accurate drug delivery. Overview of latest developments in nanomachines or nanobots are also given in this paper.

Keywords - *Applications in medical and mechanical, nanobots, nanomachines.*

I. INTRODUCTION

Nanotechnology is the engineering field in which study of things is done at nanoscale. The designing, creation, synthesising, manipulation and application of material occurs at nanoscale. [1]. Nanorobotics is study of robots at nanoscale. Nanorobots are robots of size few hundred nanometres or below comprising of various components of nanoscale size.Nanorobotics is the rapidly developing technology in field of creating robots whose components are at or close to nanoscale. Nanoroboticsis an engineering field in which designing and fabricating nano robots, with devices size ranging from 0.110 micrometres and construction of nanoscale is done. The other names used to refer nanobots are nanoids, nanites, nano machines or nanomites names have also been used to describe these devices currently under research and development [2]. Nanobots consists of two words Nano and Bots. Nano meaning extremely small. It may be measurable as nano-second, which is one billionth of a second 10^-9 and Bot is short form for robot, which is a machine which may be controlled by programming it. There are many concepts developed on nanorobots. We can use this technology to create mechanisms that can be applied in various fields such as medical, military, etc. Robotics, in present world is rapidly growing field. Design, research and development of new robots for various applications is being done. [4]. In 1988, a Scientific American article by A.K. Dewdney on the work of nanotechnologist K. Eric Drexler created public interest in the field of nanotechnology. The article portrayed potential of nanoscale machines that could operate in any environmental conditions. The applications range from medical to industrial to large buildings. [5].

II. KEY COMPONENTS OF NANOBOTS

In order for proper functioning of nanorobots following key components and design attributes are considered:

- Size and shape
- Sensors
- Means of mobility/propulsion
- Power generation
- Data storage
- Telemetry and transmission
- Control and navigation.

A. Size and Shape

Depending on the function and environmental conditions the size and shape should be considered. The first-generation reservoir nanorobots may be a simple spherical ball like shape. Latter designs may be shaped like bacteria or crawlies to enhance movement withindifferent pore systems. A major design criterion is the minimum size.

B. Sensors

Nanorobot must be able sense the borehole and reservoir parameters. Thus, it should be capable of sensing

- reservoir fluid type
- reservoir temperature
- formation pressure
- basic petrophysical properties
- fluid analysis
- trajectory and position

One or two sensors may be enough for the job for the early prototypes. The latter design may include more of the desired sensors.

C. Means of Mobility/Propulsion

This is an important design consideration for the reservoir nanorobot. Early designs are ball like without self-propulsion mechanism. They may simply be injected into the reservoir with normal injection water and are allowed to navigate their paths through the reservoir following the natural path created by the injection water or the oil flowing naturally to the producers.

D. Power Generation

Power is the major requirement for device. Nanobot requires power to perform certain function. The power required may be tens to hundreds of picowatts to even micro-watts, depending on the functions. Potential means of generating power for the nanobot are:

- Power from fluid flow or counter-current motion.
- Power derived from the reservoir temperature.
- Power from friction with rock fabrics.
- Downhole fuel cell generation from in-situation hydrocarbon.
- Use of downhole recharges station.

E. Data Acquisition and Storage

For, the nanobot to fulfil some of its functions data acquisition and storage is necessary. Quantum computing may help in the future nano-sized data storage.

F. Telemetry and Data Transmission

In recent findings by UC Irvine researchers, Zettl et al. and Burke who showed up a working radio built from carbon nanotubes that have only few atoms across, show some possibilities of transmitting data at nano-scale.

G. Control and Navigation System

Another desirable feature is the ability to control the bots from the surface.

III. APPLICATIONS IN MEDICAL FIELD

Nanomedicines are having their size of nanoscale. Richard Feynman introduced the concept of miniaturized machines that could be swallowed and work like a surgeon. [6]. They repair the effected organs of human body. Molecular nanotechnology is the latest development in nanomedicine. The precision, effectiveness, speed of treatment of diseases increases. They can easily travel the human body. Glucose and oxygen might be a source for propulsion. Early diagnosis of diseases and targeted drug delivery is important feature of nanomedicines. Nanorobots are used to break the tiny blood clots which are difficult to treat by conventional surgeries. [8]. Deep brain tumours are treated using nanorobots. Various dangerous diseases such as HIV, cancer and many other harmful diseases are under radar for using nanobots as cure. These nanobots will find the lost tissues and restore them. Nanobots are helpful for diagonising the disease, monitoring them and target the sickness.

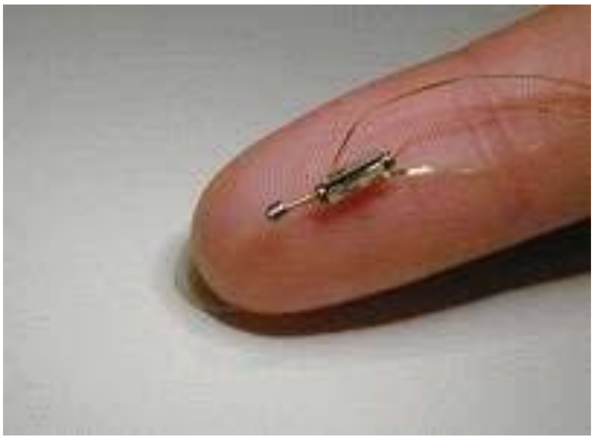


Fig.2. Device Using Nanobots for Checking Blood Contents.[2]

A. Drug Delivery System

Nanobots are just several nanometres wide which perform a specific function. They can be used very effectively for drug delivery. Drugs navigate through entire body before they reach thetargeted site. Using nanotechnology, the drug can be targeted to a precise location. This would make drug more effective and chances of side effects are reduced.Above fig.2. shows a device, a nanobotwhich monitors the sugar level in blood. A great advantage of nanobots is they control the time for drug release and amount of drug. This is controlled by controlling the electrical pulse.

B. Disease Diagnosis and Prevention

Nano biotech scientists have successfully produced microchips that are coated with human molecules. When the molecules detect disease, the chip emits an electrical pulse. Special sensor nanobots are fitted under the skin which detect the signs of disease. They can also be used to monitor the sugar level in the blood.Heart-attacks are caused by fat deposits blocking the blood vessels. These can be used to prevent heart diseases. Nanobots can be made for removing these fat deposits. The following figure shows nanobots removing the yellow fat deposits on the inner side of blood vessels.

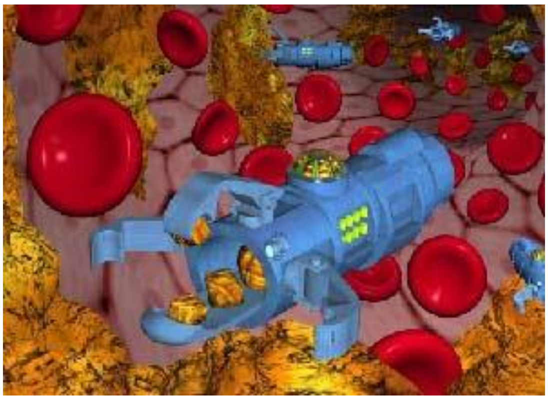


Fig.3.Nanobot preventing heart attack. [2]

C. Nanobots in cancer treatment

Cancer can be successfully treated with the help of the nanorobotics. The side effects of chemotherapy can be decreased by using nanobots since efficient targeted drug delivery takes place. Nanorobots with embedded chemical biosensors can be used to perform detection of tumour cells in early stages of development inside the patient's body. Integrated nano sensors can be utilized to find intensity of E-cadherin signals. The genetically modified salmonella bacteria carry nanobots which are about 3 micrometres in size that release the drug when they reach the tumour. The nanobot attacks the tumour leaving alone the healthy cells. This prevents the patient having sideffects of chemotherapy. The important factors for successful treatment of cancer without any side effects has targeted drug delivery and early detection of cancer before metastasis has begun. [4].

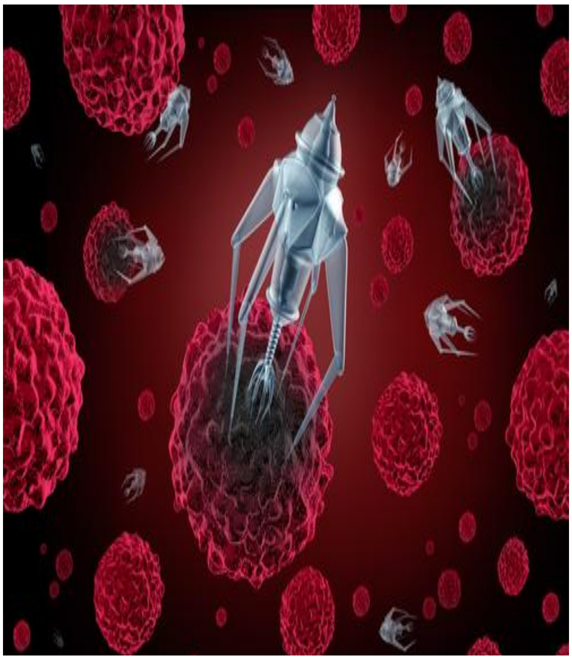
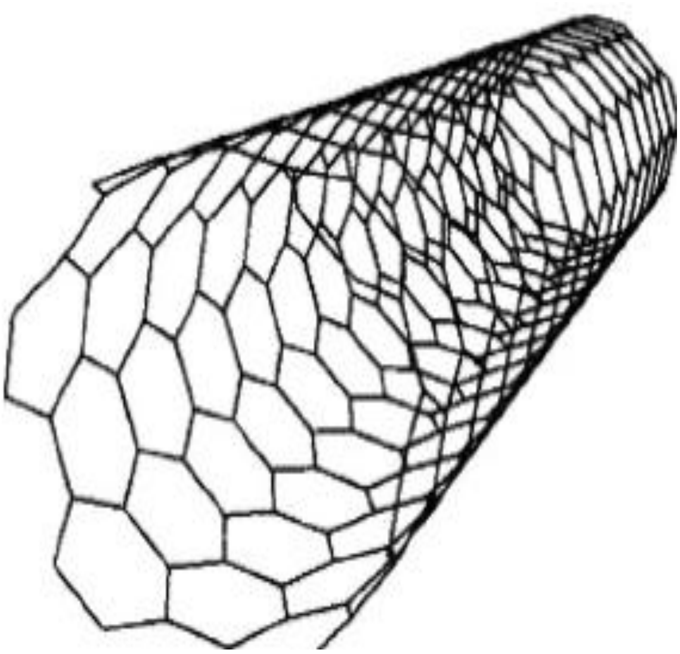


Fig.4.Nanobot treating cancer cell

IV. MECHANICAL APPLICATIONS

The mechanical application of nanobots includes biomechanics and nanomachines. The current focus modern science and technology is to develop nanomachines. Nanotubes tweezers have been demonstrated. Nano joints and various other nanostructures using carbon nanotubes have been made which further help in making a complex mechanism required for nanobot. Using fullerene structures anano sized car was made which exhibited rolling motion on gold substrate. Synthesizing molecular motors using bottom up approach and self-assembly shows progress of chemists. While engineers and physicists explore top down approach to nanoscale engineering through lithography and scanning probe microscope. Availability of nanoactuators can be guaranteed for motion of links and joints in nanobots and nanomachines. [7]



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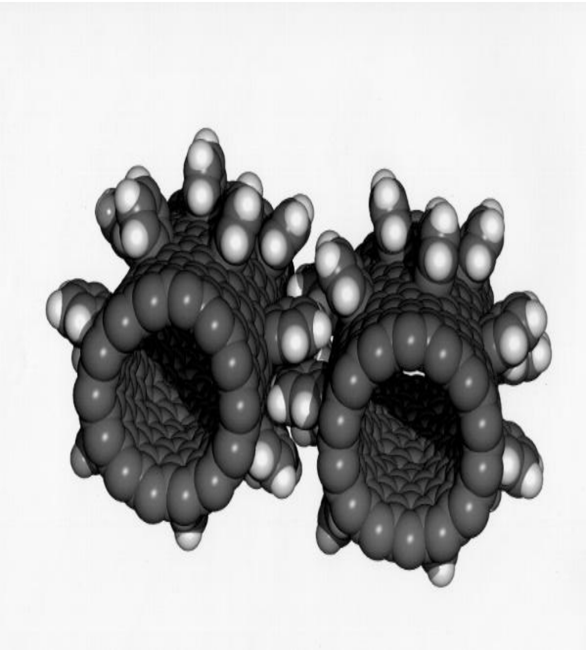

Fig.5.Fullerene nanogears [Ref: Wikimedia commons]

V. RECENT PROGRESS OF MAN-MADE NANOMACHINES

The nanoscale mechanical devices that can convert optical, electromagnetic, acoustic and chemical energy into controlled mechanical motions. Nanobots are also known as nanomachines. Nanomachines can be categorized into three types on the basis of materials used to make them:

1. molecular machines, such as deoxyribonucleic acid (DNA)
2. ribonucleic acid (RNA)
3. stereo-organic molecules

Upon receiving the stimulus, the nanomachines perform mechanical movements. Due the 3D random positioning and thermal induced Brownian movement, it is difficult to synchronise the motions of large number of molecules for practical applications. The second type of nanomachines are made of inorganic nanoparticles.The stimulation with physical fields or chemical reaction cause the nanomachines to transport, rotate, roll, drill, wobble. The third type is bioinorganic hybrid nanomachines. Rotary proteins or cardiomyocytes are examples of biocomponents for nanomechanical device which serve as engines to drive the inorganic components of the devices into motion. The sizes of the devices range from a few micrometers to a few millimetres.

A. Nanomachines fabricated by top-down lithography

` Mechanical devices such as microscale motors, resonators and accelerometersare developed using top-down lithographical techniques. The lithography techniques are photolithography and micromachining. [6].

1) Rotary Nanomachines with Multiwalled Carbon Nanotubes as Bearings

Zettl's group at UC-Berkeley, designed and fabricated rotary nanomachines which consists of nanoscale metallic plates as rotors and multiwalled carbon nanotubes (MWCNTs) as bearings through multi-step electron-beam lithography (EBL). The metal plate of 250–500 nm sides, is patterned onto a piece of MWCNT. On the two electrodes, the entire piece is suspended. It oscillates between two angles by DC electric voltage of 50V. The outer plates of MWCNT has nanoplate attached and entire thing has over 80V. There is ultra-low friction between outer shell of MWCNT attached with nanoplate rotor and inner shells of MWCNT. Therefore, slippage occurs. [6]. Such devices could be applied to high-frequency torsional resonators and robust rotational NEMS actuators.

B. Chiral metamaterial made of Nano helices

The twisting of molecules left handed or right-handed forms is called chirality. It crucial to understand as it changes the way molecules behaves within our bodies. Moleculestwist in certain ways and depending on twist, it can exist in left or right 'handed' forms. This twisting, called chirality, is crucial to understand because it changes the way a molecule behaves within our bodies.

University of Bath, Department of Physics, researchers working with colleagues from the Max Planck Institute Systems have used smallest springs to examine how effective the gold springs could be at enhancing interactions between light and chiral molecules. SHG (second harmonic generation) is the colour conversion for light which enhances the performance of spring. The more red laser light converts into blue laser light.[9].

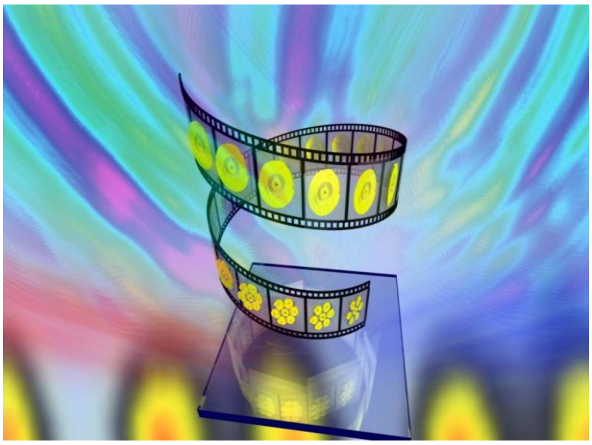

Fig.7.Gold spring-shaped coils 5,000 times thinner than human hairs offer promising application through the interaction of their helical shape with light. [9].

Physics PhD student David Hooper who is the first author of the study, said:"The picture becomes distorted when we rotate the kaleidoscope. We need to minimise the distortion." In order to reduce the distortions, the team is now working on ways to optimise the springs, which are known as chiral nanostructures.

Dr. Ventsislav Valev who led the study and research team of University of Bath, Department of Physics said "Closely observing the chirality of molecules has lots of potential applications, for example it could help improve the design and purity of pharmaceuticals and fine chemicals, help develop motion controls for nanorobotics and miniaturise components in telecommunications." [9]

C. Graphene engine for nanorobots

Graphene is a 2D sheet of carbon atoms that have great mechanical strength. Recently, researchers from Singapore showed a nano-sized engine made from a highly elastic piece ofgraphene. The sheet expands when chlorine and fluorine molecules are inserted in graphene lattice and fired by a laser. When the laser is alternatively and rapidly turned ON and OFF the graphene pump moves back and forth like a piston of IC engine. Researchers think this graphene nano engine can be used to power tiny robots for example to attack cancer cells. There is no degradation of engine even after 10,000 cycles and also it is highly energy efficient. The researchers demonstrated that the graphene engine shows exceptional reliability. [10].

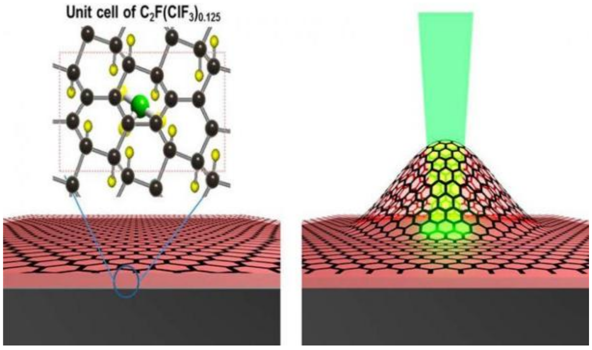

Fig.8. Graphene Bulge. [10]

D. 3D-motion nanomachines from DNA

Mechanical engineers at The Ohio State University have proved that basic design principles that are applied to full size machine parts can now be applied to DNA origami. In future,a controllable and complex component for nanobots can be made. The DNA origami method is a method for making nanostructures which has been used since 2006. Now it is used in many labs for developing future drug delivery systems. Long strand of DNA strands and coaxing them to fold onto different shapes and also securing certain parts together with staples made from shorter DNA. A stable structure is formed which can perform stable basic such ascarrying small amount of medicine in a container like DNA structure and opening the container to release it. [11].

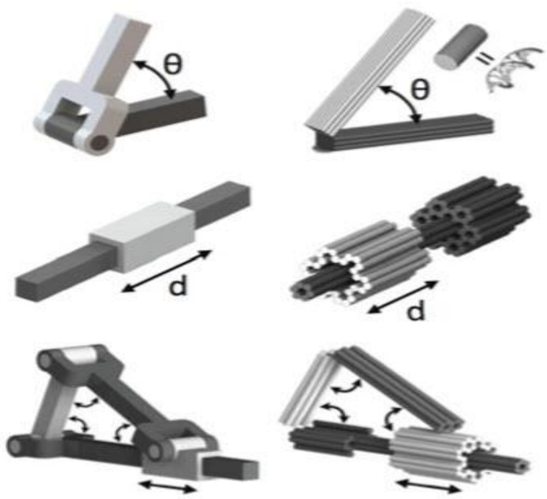

Fig.9. DNA origami mechanism design. Top isolated joints, middle for linear motion. Joints can be integrated for complex motion such as crank-slider mechanism. (bottom). [11].

There are two keys unique approach for designing and controlling the machines motion-

1. Making certain parts of DNA flexible using single stranded DNA and stiffer using double stranded DNA.
2. DNA structures should be changed such that movements are reversible and repeatable. For this, researchers dot the structures with DNA strands that hang off the edges. These strands act as hook and loop fasteners.

The researchers built a system that moved a piston inside a cylinder. That particular machine had around five planks, two tubes of different diameter and three hinges all made from pieces of double-stranded and single-stranded DNA. TEM-Transmission Electron Microscopy was used to test whether machines were moving properly. The DNA was fluorescent tagged so that the shape changes can be observed with a spectroflurometer.

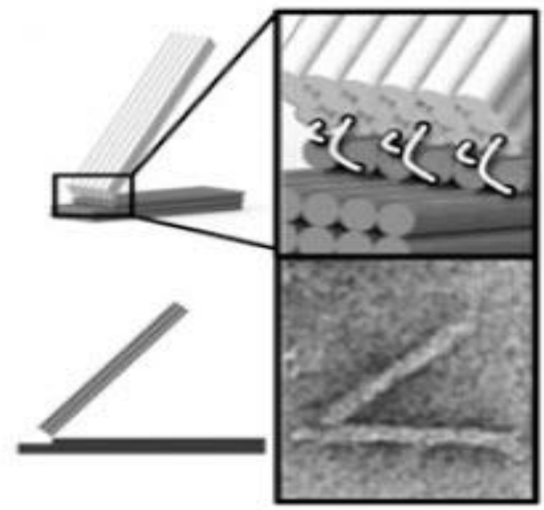

Fig.10.DNA origami hinges. [11].

These tests confirmed that the piston moved back and forth when hinges opened and closed. The researchers controlled the motion by adding chemical cues to solution.The engineers say this is the first time it's been done with DNA, and the first time anyone has tuned theDNA to produce reversible actuation of a complex mechanism. This research was funded by the National Science Foundation (NSF) and the Center for Emergent Materials at Ohio State. [11].

E. Nanoswimmers

An elastic nanoswimmer made of polypyrrole nanowire about 15micrometres long and 200 nanometres thick was developed by ETH Zurich and Technion researchers. It can travel through the biological fluid environments at almost 15 micrometres per second. Nanowire tail made of two hinged ferromagnetic nickel sections of the wire,surgeis controlled by an oscillating magnetic field, which causes the tail to allow also surgeand move forward .Nanorobotic swimmer must employ nonreciprocal (non-time-symmetric) motion to achieve net displacement. Purcell stated that, in a viscous Newtonian fluid, the simplest structure capable of nonreciprocal motion at a low Reynolds number is a fore-aft-symmetric linkage, with three links separated by twohinges. [12]. Thenano swimmers could be used to for drug delivery.

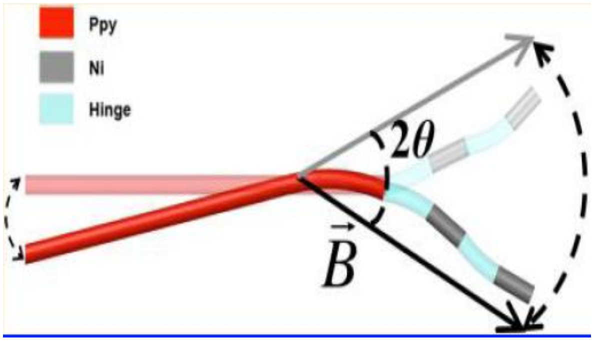

Fig.11. Schematic of 3-link nanoswimmer with undulation motion driven by an oscillating magnetic field. [12].

VI. ADVANTAGES OF NANOBOTS

- Breaking up blood clots: Blood clots can cause muscle deaths and strokes. Nanorobots can to travel to a clot and break it up. This application is one of the most complex and sophisticated uses for nanorobots.
- They help in performing painless and non-invasive surgeries.
- They help to get rid of diseases quickly without any side effects.
- They work only on a particular site only.
- Less post treatment care required.
- The initial cost of development is only high but batch processing reduces cost of manufacturing.
- The diagnosis and monitoring is continuous and done from inside of the body.
- They disassemble and get excreted after completion of task, if necessary.
- Durability of nanobots is high.
- No tissue trauma.

VII. LIMITATIONS OF NANOBOTS

- The designing cost is very high.
- Nanotechnology has higher risk in field of terrorism.
- Functioning of nanobot should be accurate otherwise it will have negative effects.
- Design of nanobots is very complicated.
- Hard to interface and control externally.

VIII. CONCLUSION

This paper is a review on the nanobots. The nanobots have many applications especially in the field of medicine. These nanobots designing and manufacturing process is expensive but they are important for medical applications. In the mere future nanobots would become integral part of medical field. It has numerous applications in medical field which are more effective than the conventional medical treatment. With each day, the advances in nanoscale actuation brings us close to a world of nanotechnology and nanobots. Nanobots has certain limitations such as initial expenses are high. Butfuture healthcare will have sensitive new diagnostics for an improved personal risk assessment.

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