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Current and Future Methods for the Synthesis and Application of Nanorobotics

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Research and development of robotics over the last decade has increased exponentially; robotics achieves automation and precision which desirable features in many scientific research and development facilities. One main issue with robotics is that they cannot perform all tasks, and this is particular true when working on a smaller scale. This is where nanorobotics becomes the next step in the evolution of scientific research and application. Nanorobotics is a form of nanotechnology which has recently become a more applied and extensively studied in the scientific community. Applications range from nanominipulators to nanomaterials (Mavroidis and Ferreira 2013) which can consist of nanoparticles or carbon nanotubes made of a single layer of carbon atoms. Nanorobots are characterized as any structure able to perform one or more of the following tasks: actuation, sensing, manipulation, propulsion, signaling, information processing, intelligence, and swarm behavior at a scale of 10^{-9} meters also known as nanometers (Mavroidis and Ferreira 2013). These allow for the study of particles and the manipulation of atoms to create never before seen materials with amazing characteristics. The next logical step is to take robotics and shrink it to a nanoscale. The material covered in the next few paragraphs will outline the possible methods of nanorobot creation, their current application, and possible future advances.

Nanorobotics is still in its infancy of research and development, but there exists a few techniques to aid in the creation of the robots. A popular nanotechnological material is carbon nanotubes (CNTs). These structures are widely used and have been the main topic of much nanomaterial research. One way of producing CNTs is by electrochemical syntheses; this process involves the decomposition of carbon monoxide or other carbon compounds in an electrically charged solution depending on the required diameter and length of the needed CNT. The chemical makeup of the solution, its temperature, and the reactants involved are changed to tailor the process to produce the desired dimensions (Coleman 2011). The use of these CNTs in nanorobotics is extensive because of their incredible strength and the possibility of extensive structures. One approach to manipulate such materials on a nanoscale was developed by physicists, but nanorobotics was not their primary focus (Mavroidis and Ferreira 2013). Atomic force microscopy (AFM) was invented by Binnig, Quate and co-workers in 1986 to produce high resolution images of atomic structures on surfaces (Mavroidis and Ferreira 2013). The original instrument measured the displacement of a cantilever with a scanning tunnelling feedback signal in order to measure the force acting on it caused by the displacement of an atomically sharp tip moving across the surface of a structure (Binnig *et al.* 1985). This device was soon upgraded to use the very accurate displacement of a reflected laser to provide the feedback signal used to produce an image of the surface. This tip is about one atom in size which allows for the extremely high lateral resolution (Binnig *et al.* 1985). It was subsequently found that the AFM has the capability to manipulate atoms and atomic structures (Mavroidis and Ferreira 2013). The device is able to do this by manipulating the atomic forces between two atoms (Mavroidis and Ferreira 2013). Although this technique still struggles to consistently control the exact placement of atoms, it is still one of the best approaches currently available.

Graphene is a nanomaterial which consists of a single layer of carbon atoms arranged in a hexagonal shape (Brody 2012). This nanomaterial has incredible characteristics which were enough to constitute the Nobel Prize for the physicist, Andre Geim, who created it (Brody 2012; Noorden 2012). This material is easily made by sticking a piece of tape to the tip of a graphite pencil and then continuously sticking the tape to itself until a few flakes are only one carbon atom in thickness (Noorden 2012). This incredible material is very strong and yet flexible (Brody 2012). Although graphene is difficult to produce on a large scale the applications of this nanomaterial are endless in producing nanorobots.

One of the possible definitions of nanorobotics is a device that manipulates matter on the nanoscale; this definition suggests that many forms of nanorobotics exist today. Going back to the AFM and STM, these both are able to manipulate atoms, sense atomic structures, and provide feedback to produce the high resolution image; this means that these machines are in fact considered to be in the field of nanorobotics. Not only were manipulators developed, but nanocomputers and nanomotors have also been produced (Mavroidis and Ferreira 2013). A nanomotor was created recently which was capable of fitting in an average animal cell (Mashable). This motor was able to spin at rate of 18 000 RPM and had a run time of about half a day (Mashable). This motor falls along the lines of self-propulsion so therefore it is classified as nanorobotics. Dr. Donglei, the leader of the research team behind the motor, has named the technology Ultrahigh-Speed Rotating Nanoelectromechanical System or (NEMS) for short (Mashable). The team also uses a technique that Cornell University invented called electricstatic tweezers (Mashable) which allows for the extremely precise positioning and rotation of the nanomotors down to 200 nanometers (Mashable). This nanomotor can possibly revolutionize the world of medicine with applications that can range from drug delivery to the search and destruction of cancer cells which is exactly what the researchers at Cornell University are aiming to achieve. They soon hope to be able to have the motor working within a cell or to even create a swarm of motors which work together to repair damaged cells or destroy dangerous foreign materials (Mashable). Research on magnetically guided nanorobots has led to the successful manipulation and propulsion of a particle using a magnetic resonance imaging machine (MRI) (Mavroidis and Ferreira 2013). The particle consisted of approximately 10μm magnetic microparticles which were guided through a blood vessel untethered using magnetic fields produced by an MRI (Mavroidis and Ferreira 2013). This is still considered nanorobotics even though the propulsion has been externalized as opposed to being in the particle (Mavroidis and Ferreira 2013). Current advances in nanorobotics and the synthesis of nanomaterials points towards a strong and reliable future for the field of nanorobotics.

With the recent development of theses NEMS devices and ongoing research towards CNTs and the use of electromagnetic particles and magnetic fields to induce propulsion, and the amazing strength, flexibility, and conductivity of graphene, the future of nanorobotics is promising. The medical applications of nanorobotics are extensive and the only limitation seems to be the imagination of human kind. The use of nanomaterials and quantum dots allow for incredibly small computer processors and memory storage never before thought possible. Given the current development of nanorobotics it is possible to imagine that developments will soon see computers capable of creating incredibly detailed analysis, work that will be able to simulate the neural pathways of the human brain, and devices able to pilot extensive interstellar missions. One can envision nanorobots capable of cell repair being used in hospitals or conversely military applications of a swarm of nanites capable of eating through nearly any material. It may also be possible to increase the neural capacity of human helping us to remember more, do increasingly complex calculations, or even mimic splinter abilities shown in rare cases such as Laurence Kim Peek, commonly known as Rain Man. These ideas seem straight out of science fiction but are becoming increasingly viable in the realm of nanorobotics.

In conclusion the current synthesis of nanomaterials, available nanorobotics technology, and future applications of nanorobotics make the field very promising and full of many potentially ground breaking research opportunities. The field of nanorobotics may not be a well-known nanotechnology at the moment, but in time new discoveries will advance human kind over the decades. Although the research behind nanorobotics is limited and is still new in the scientific community, it is clear that nanorobotics is extremely promising and will aid in the evolution of medical, mechanical, and chemical sciences.

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