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NANOTECHNOLOGY AND APPLICATIONS OF NANOTECHNOLOGY IN MEDICINE

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ABSTRACT: Nanotechnology can be characterized as the science and engineering involved in the design, synthesis and applications of materials and devices which have at least one nanometer scale, or one billionth of a meter, of the smallest functional organization. At these scales, in relation to the bulk macroscopic properties of the substance or system, consideration of individual particles and communicating groups of molecules becomes important as control over the fundamental molecular structure allows control over the chemical and physical macroscopic properties. Medical and physiological applications include materials and instruments designed to communicate with the body with a high degree of precision on subcellular (i.e., molecular) scales. This can theoretically translate into complex clinical applications for targeted cells and tissues engineered to achieve optimum therapeutic benefits with minimal side effects. This overview explores the key scientific and technological aspects of nanotechnology and addresses some of its possible clinical applications.

KEYWORDS: Design, Material, Nanometer, Nanotechnology, Physiological, Synthesis.

INTRODUCTION

In different areas, including medicine and physiology, nanotechnology and nano-engineering are responsible for making important scientific and technological advances [1]. They can be characterized in a broad sense as the science and engineering involved in the design, synthesis, characterization and application of materials and devices with at least one dimension of the smallest functional organization on a nanometer scale, ranging from a few to several hundred nanometers. A nanometer, around the size scale of a molecule itself, is one billionth of a meter or three orders of magnitude smaller than a micron (e.g., a DNA molecule is about 2.5 nm long while a sodium atom is about 0.2 nm) [2]. To offer an idea of just how critical an order of magnitude is, let alone three orders when going from micron to nanometer scales, consider that no one will ever walk from New York to San Diego, but you will get to San Diego across the United States in about 2 days with a single order of magnitude change in speed (the equivalent of shifting speed from walking to driving). In a few hours, flying, which would be two orders of magnitude faster than walking, would get you across the United States and it would take you minutes in a supersonic plane (or three orders faster than walking). (It will take about 42 days at an average speed of 3 miles per hour to walk a straight line between the two cities.).

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The potential effect of nanotechnology stems directly from the consideration of spatial and temporal scales: nanometer-scale materials and devices suggest controlled manipulation of individual constituent molecules and atoms in the manner in which they are arranged to shape the macroscopic bulk a substratum. This, in turn, implies that, as a result of control over their molecular synthesis and assembly, nano-engineered substrates can be built to exhibit very precise and controlled bulk chemical and physical properties [3]. These materials and devices can be engineered to communicate with cells and tissues at a molecular (i.e. subcellular) level with a high degree of functional precision for applications in medicine and physiology, thus enabling a degree of integration between technology and biological systems not previously attainable. It should be noted that nanotechnology is not a single emerging scientific field in itself, but rather a meeting of conventional sciences, such as chemistry, physics, materials science and biology, in order to put together the combined knowledge necessary to create these new technologies. The key synthetic and assembly methods used in nanotechnology are presented in this review and emerging technology is being developed. Checked for biological and medical applications.

The first segment will provide a brief summary of nanotechnology's key synthetic methods and will aim to provide a sense of how to manipulate matter on such a small scale. Some of the specific engineering challenges imposed by such limited spatial (and temporal) scales will be the subject of the second section. Some general applications of nanotechnology to medicine and biology currently being developed will be defined in the third section. An introduction to this new science is represented by this article. Future Surgical Neurology papers will concentrate and build on the potential of nanotechnology to treat disorders of the central nervous system (CNS) and address the particular challenges posed by the CNS [4].

Synthesis

Precursors from solid, liquid, or gas phases and phases can be accommodated by different methods for the synthesis of nano-engineered materials and devices. A tremendously complex collection of experimental techniques that are beyond the scope of a brief introductory overview are included. In general, however, it is possible to divide most synthetic methods into two key approaches: "top down" and "bottom up" approaches and combinations of them. Top-down techniques start with and integrate smaller-scale information into a macroscopic material or group of materials. The photolithography technique used by the semiconductor industry to create integrated circuits by etching patterns in silicon wafers is the best known example of a 'top down' approach. In general, this approach begins by covering a piece of silicon with some kind of photoresist, a sensitive photochemical, a polymer that hardens at particular wavelengths when exposed to laser light. Patterns are then "drawn" with a laser into the photoresist-coated silicon so that it is possible to wash away the untreated photoresist and treat the exposed silicon so that it can serve as an electrode.

After extracting the hardened photoresist to yield transistors, aluminum wires are then put down in the engraved patterns. In order to research neuron-astrocyte contact, a similar method was used to build microscale linked wells in agar using poly (di-methyl-siloxane) molds. Cell cultures are established where neurons are in one well and astrocytes are linked by a channel in an adjacent well that allows soluble factors to spread [5]. This is an example of a cell biology-applied lithographic technique. Other types of nano-lithographic techniques, such as dip pen nanolithography and electrostatic atomic force microscope nanolithography, are capable of producing true nanoscale characteristics in various materials where individual molecules are deposited or moved, respectively, into desired configurations [6][7].

Spatial and Temporal Considerations

It is important to appreciate that the principle scientific and engineering obstacles involved in developing nanotechnology applications stem from the inherent size and time scales being considered, from a few to about a hundred nanometers spatially and from nanosecond to femtosecond time scales if atomic bond oscillations need to be taken into account, for example: A femtosecond is six orders of magnitude smaller then a nanosecond, a billionth of a nanosecond or 10-15 seconds, an incomprehensibly small unit. Because the molecular building blocks being manipulated are on such a small scale, these substrates have spatial and/or temporal levels of organization that span several orders of magnitude, with different levels nested within higher order levels (e.g., 6 orders of magnitude for a device that has a nanoscale ultrastructure but a millimeter macroscopic structure). Therefore, to study and explore these rich and complex systems, highly sophisticated theoretical and experimental tools are required.

In particular, sophisticated imaging and quantitative techniques with spatial and temporal resolutions of 10 to 6 (the size of a micron-a red cell is 7 microns in diameter) and below the molecular level are needed for the visualization, characterization, and manipulation of materials and devices. Furthermore, these methods are essential for understanding the connection and interface between a especially important target for biological applications: nanoscopic and mesoscopic/macroscopic scales. As such, the simultaneous development of these physical characterization techniques would require more nano-technological advances.

Applications in the field of Medicine

Microelectromechanical systems (MEMS) and biocompatible electronic devices that have considerable potential to enhance the treatment of many disorders are recent developments in tissue engineering that have occurred at levels greater than the nanoscales mentioned above [8]. Despite this potential, however, both of these methods rely on bulk molecular engineering or chemical manipulation of macromolecular (mostly polymer) structures that lack the ability to manipulate the structure of the nanoscale. A much greater degree of integration between technology and physiological structures should be provided by nanoengineered materials and devices designed to communicate with cells and tissues or perform biologically specific functions [9]. This, in turn, could ultimately translate into novel clinical applications and alternatives for treatment. Currently, medical and physiological applied nanotechnology is in its infancy, with much of the studies at the basic science level as the sector seeks to organize

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itself. As such, viable therapeutic implementations are still years away, but the scale and pace of current research is remarkable in spite of this. New drug delivery systems (in some cases, specifically for the blood brain barrier) using nanoparticles are one example of such an application or highly porous bilayer tubule systems for self-assembling [10]. Chemically functionalized dendrimers, highly branched molecules with a "tree-like" branching structure that can be used as molecular building blocks for gene therapy agents or as contrast agents for magnetic resonance imaging (MRI) are another class of applications being developed.

For gene therapy applications, dendrimers are desirable molecules because they are a non-viral DNA delivery mechanism (an important clinical consideration) that appears to wrap itself in the branches of dendrimers. Increased relaxivity, the induced spin relaxation time of surrounding water protons, which translates into greater contrast images, has been shown to generate Dendrimer-based MRI contrast agents. Specialized membranes for the separation of low-weight organic compounds from aqueous solutions have been established by filling microfiltration pores or ultrafiltration membranes with functional polymeric molecules (i.e. pore sizes in the order of microns and smaller) that have an affinity for filtering compounds. This nanomembrane can, for example, allow very selective ultrafiltration of toxic physiological compounds. Furthermore, much research is going into functional nanodevices that are biologically inspired, such as the development of DNA/polymerase chain reaction.Molecular computers or protein-based molecular computers that encode information in nucleotide sequences of DNA molecules or in protein tertiary structures and perform computations by following different pathways of biochemical reaction. Biomimetic self-assembling molecular motors, such as bacterial flagella, or mechanical forces generated by RNA polymerase during protein transcription, are also of interest [11].

These molecular motors provide excellent examples of biological self-assembly that naturally occurs, as they consist of various molecular "parts" that self-assemble to create the functional structure and are important targets for studying and emulating the production of synthetic nano-motors that can, for instance, interact with biology. These applications are only a few examples of recent research in nanotechnology targeting medicine and physiology. For general cellular processes, such as ubiquitous signaling pathways that can support various physiological systems, nanotechnology development is being pursued. The particular challenges of specific diseases, such as diabetes mellitus or arteriosclerosis, are also targeted. Every pathophysiological process ultimately has a molecular origin, and the enormous potential of nanotechnology applications for medicine emerges from this fundamental fact.

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