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NANOSCIENCE AND THEIR BIOLOGICAL IMPORTANCE: HUMAN HEALTH AND DISEASE

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Nano-science is at the leading edge of the rapidly developing field of nanotechnology. Several areas of medical care are already benefiting from the advantages that nanotechnology can offer. Applications of nano-science in biotechnology, medicine, pharmaceuticals, physics, material science and electronics are also covered in this review. Mankind is still fighting against a high number of serious and complex illnesses like cancer, cardiovascular diseases, multiple sclerosis, Alzheimer's and Parkinson's disease, and diabetes as well as different kinds of serious inflammatory or infectious diseases (e.g. HIV). Most of theses diseases have a tremendous negative impact not only on the patient himself but also on the whole society and linked social and insurance systems. It is of utmost importance to face these plagues with appropriate means. This brief review tries to recapitulate the most recent developments in the field of applied nano-science, particularly in their relevance in treatment of various diseases and their biological importance in human health and to discuss their future prospects.

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1. Introduction

Nano-science is well recognized as a revolutionary step in various field of science and a logical field of study for researchers in the coming years as it is, the study of fundamental principles of molecules and structures between one nanometer (one billionth of a meter) and 100 nanometers in size. Due to the novel design and size-tunable optical properties of nano-materials with new physico-chemical characteristics [1], their potential adverse impact on human health must be addressed.

Nano-materials are structurally and functionally prevalent in the organic, inorganic, and biological fields. Their unique size-dependent properties make these materials superior and indispensable in many areas of human activity. The biological application of nano-particles is a rapidly developing area of nanotechnology that raises new possibilities in the diagnosis and treatment of various diseases. Basically, the nano-meter length scale opens the way for the development of novel materials for use in highly advanced medical technology. As researchers are developing an ever-expanding toolkit of nano-particles for use as drug and imaging agent delivery vehicles, there is a growing need to understand how a given nano-particle's physical and chemical properties affect biological activity and toxicity. Now, various new methods have been developed

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for measuring the biological activity of nano-materials in a highly systematic manner that enables them to draw important insights about nano-material biologic activity.

2. Nanotechnology products

Nanotechnology has created a growing sense of excitement due to the ability to create and utilize materials, devices, and systems through the control of matter on the nanometer scale (1 to 50 nm). Current and near-future developments in medicine are of interest, because it can be projected beyond them to perceive what will be possible once inexpensive nano-scale manufacturing of highly functional products becomes a reality.

Manufacturing with nanotechnology can solve many of the world's current problems. After more than twenty years of basic and applied research, nanotechnologies are gaining in commercial use. Nano-scale materials now are in electronic, cosmetics, automotive and medical products. Various investigations are continuing researches are now established in the area of nano-materials, in which scientists use different cell lines for their assays and measured biological activity at different nano-particle doses.

New concepts for regenerative medicine give hope to many patients with organ failure or severe injuries. Nano-particle reinforced polymers [2], orally applicable insulin [3, 4], artificial joints [5, 6] made from nano-particulate materials, and low-calorie foods with nano-particulate taste enhancers. Some products are already commercially available, such as surgical blades and suture needles, contrast-enhancing agents for magnetic resonance imaging [7], bone replacement materials [8], wound dressings [9, 10], anti-microbial textiles, chips for in vitro molecular diagnostics, micro-cantilevers, and micro-needles. With the emergence of technologies to fabricate and mass-produce micro-scale tools and micro-machines, micro-surgery stands to potentially benefit through the development of a fundamentally new class of instruments. These new instruments may provide the surgeon with access to the smallest reaches of the body and perform operations that are currently not possible with manually operated tools [11]. Nano-wires are tiny highways for electrons, transporting them quickly and efficiently through the solar cell. This analysis clearly showed that there were definite correlations between the physical and chemical properties of a nano-particle and biological activity.

3. Nanoscience and biotechnology

Nanotechnology will have an almost endless string of applications in biotechnology, biology, and biomedicine. The biotech world also has many real world applications currently in use or under development that are, or will be, affecting our quality of life. However, nano-biotechnology presents a promising research and development frontier with a tremendous future impact in the following areas:

Drug delivery: Novel therapeutic strategies include the development of targeted transport vehicles allowing drug delivery to specific cells or cell structures. Of particular interest are bioengineered nano-particles, which can be utilized as transport vehicles of diagnostic or therapeutic agents [12]. Drugs with narrow therapeutic indexes create a major challenge for pharmaceutical scientists, during their developments. Application of nanotechnology for the delivery of such drugs can significantly overcome this problem [13, 14]. Nucleic acid ligands, also known as aptamers, are a class of macromolecules that are being used in several novel nano-biomedical applications, which collectively make them attractive molecules for targeting diseases or as therapeutics. These properties will enable aptamers to facilitate innovative new nanotechnologies with applications in medicine [15].

Magnetic nano-particles (MNPs) possess unique magnetic properties and the ability to function at the cellular and molecular level of biological interactions making them an attractive platform as contrast agents for magnetic resonance imaging (MRI) and as carriers for drug delivery [16]. However, further development is required before nanotechnology can be applied clinically.

Gene therapy: Nanotechnology, using advanced polymers as a delivery mechanism, may revive genetic therapy as a tool for curing diseases. Problems with delivery systems for genes - often based on the use of viral vectors - have already caused researchers to pull gene therapy projects. Non-viral vectors, nano-particles, complexes between lipids, or polymers with DNA have been proposed as alternatives to viruses used to incorporate specific genes into target cells. Recent progress in nanotechnology has triggered the site specific gene delivery research and gained wide acknowledgment in contemporary DNA therapeutics [17]. Recently the major challenge of gene therapy for researcher is to explore whether nano-particles can be delivered intravenously to attack metastatic tumour cells, which are found throughout the body in advanced stages of cancer.

Nano-biosensors/DNA nano-chips: Nano-materials are exquisitely sensitive chemical and biological sensors constructed of nano-scale components (e.g., nano-cantilevers, nano-wires, and nano-channels) can recognize genetic and molecular events and have reporting capabilities, thereby offering the potential to detect rare molecular signals associated with malignancy [18]. Rapid and sensitive drug screening, one of the limiting factors in combinatorial chemistry for drug discovery and development, is another important application of nano-biosensors. Because of the small dimension, most of the applications of nano-biotechnology in molecular diagnostics fall under the broad category of biochips/micro-arrays but are more correctly termed nano-chips and nano-arrays [19].

The advancement of biotechnology has been facilitated the biotechnologist to have better understanding, characterization, and control of living cells.

4. Human health and disease

Nanotechnology is already starting to have an impact on the diagnosis, treatment and prevention of disease, especially by enabling early disease detection and diagnosis, as well as precise and effective therapy. It approaches in surgery, cancer diagnosis and therapy, bio-detection of molecular disease markers, molecular imaging, implant technology, tissue engineering, and devices for drug, protein, gene and radionuclide delivery. While many of these medical nanotechnology applications are still in their infancy. Nano-particles or nano-structures are utilizing as novel drug delivery systems [13, 14]. Systemic administration of chemotherapeutic agents, in addition to its anti-tumor benefits, results in indiscriminate drug distribution and severe toxicity. This shortcoming may be overcome by targeted drug-carrying platforms that ferry the drug to the tumor site while limiting exposure to non-target tissues and organs [20].

The rapid and sensitive detection of pathogenic bacteria is extremely important in medical diagnosis and measures against bioterrorism. Recent advances in the field of nanotechnology led several groups to recognize the promise of recruiting nano-materials to the ongoing battle against pathogenic bacteria [21]. Rapid, selective, and sensitive detection of viruses is crucial for implementing an effective response to viral infection, such as through medication or quarantine. Direct, real-time electrical detection of single virus particles can be achieved with high selectivity by using nano-wire field effect transistors [22].

5. Nanoscience and medical research

Research in nano-medicine will allow for a better understanding of the functioning of the human body at molecular and nano-metric level and it will thus give us the possibility to intervene better at pre-symptomatic, acute or chronic stage of illnesses. Some other nanotechnology applications which are currently under development in the biotech world are diabetic insulin bio-capsules, pharmaceuticals utilizing "bucky ball" technology to selectively deliver drugs, and cancer therapies using targeted radioactive bio-capsules. Molecular manufacturing will have major effects on medical research, diagnosis, and treatment.

Other diseases, including influenza, hepatitis B virus (HBV) and pneumococcal infection are being at least partially controlled by vaccines, but there is still much that needs to be done to eliminate many such diseases, even in the developed world [23]. With very few adjuvants currently being used in marketed human vaccines, a critical need exists for novel immuno-potentiators and delivery vehicles capable of eliciting humoral, cellular and mucosal immunity [24]. Nano-particle technology is also an attractive methodology for optimizing vaccine development because design variables can be tested individually or in combination [25].

6. Nanoscience and medicine

In recent years there has been a rapid increase in nanotechnology applications to medicine in order to prevent and treat diseases in the human body [26]. Nano-medicine (the application of nanotechnology to health) raises high expectations for millions of patients for better, more efficient and affordable healthcare and has the potential of delivering promising solutions to many illnesses. Nano-medicine, an offshoot of nanotechnology, refers to highly specific medical intervention at the molecular scale for curing disease or repairing damaged tissues [27], such as bone [28, 29], muscle, nerve chronic pulmonary diseases [30] or coronary artery disease [31]. Nano-crystalline silver products (Acticoat) is effective against most common strains of wound pathogens; can be used as a protective covering over skin grafts; has a broader antibiotic spectrum activity; and is toxic to keratinocytes and fibroblasts. Animal studies suggest a role for nanocrystalline silver in altering wound inflammatory events and facilitation of the early phase of wound healing [32]. Nano-sized cosmetic or sunscreen ingredients pose no potential risk to human health, whereas their use in sunscreens has large benefits, such as the protection of human skin against skin cancer [33]. It gives the hope of designing new, more efficient drugs with fewer or no side effects.

The development of novel materials and devices operating at the nano-scale range, such as nano-particles, provides new and powerful tools for imaging, diagnosis and therapy. The design of multifunctional nano-particles is suggested as an alternative system for drug and gene delivery, which has great potential for therapy in areas, such as cancer and neuro-pathologies [34].

Nano-medicine raises high expectations for millions of patients for better, more efficient and affordable healthcare and has the potential of delivering promising solutions to many illnesses. The aim is to identify a disease at the earliest possible stage. Ideally already a single cell with ill behavior would be detected and cured or eliminated.

7. Nano-science and cancer

The biological application of nano-particles is a rapidly developing area of nanotechnology that raises new promises in the diagnosis and treatment of various cancers. They can also facilitate important advances in detection, diagnosis, and treatment of human cancers and have led to a new discipline of nano-oncology [35]. Nano-particles offer a new method of tumour targeting, already available in clinical practice, which can concomitantly improve the efficacy and decrease the toxicity of existing or novel anticancer agents. This makes them an ideal candidate for precisely targeting cancer cells. Molecular imaging has now considered as a high area in cancer diagnosis [36]. Early assessment of nanotechnologies is also reported by Micro-array Analysis and Photodynamic Therapy [37] implementation, which methodology can be extrapolated to other nanotechnologies in oncology. [38]. In the near future, the use of nanotechnology could revolutionize not only oncology, but also the entire discipline of medicine.

The development of resistance to variety of chemotherapeutic agents is one of the major challenges in effective cancer treatment. Nanotechnology could enhance the precision of drugs that have one highly specialized mission, like finding and killing cancer cells or tumors. Additionally, multi-functional nano-carriers are developed to enhance drug delivery and overcome MDR by either simultaneous or sequential delivery of resistance modulators (e.g., with P-glycoprotein substrates), agents that regulate intracellular pH, agents that lower the apoptotic threshold (e.g., with ceramide), or in combination with energy delivery (e.g., sound, heat, and light) to enhance the effectiveness of anticancer agents in refractory tumors [39]. A recent study showed that targeting of phage nano-medicines via specific antibodies to receptors on cancer cell membranes results in endocytosis, intracellular degradation, and drug release, resulting in growth inhibition of the target cells in vitro with a potentiation factor of >1000 over the corresponding free drugs. These results define targeted drug-carrying filamentous phage nano-particles as a unique type of antibody-drug conjugates [20].

Optically efficient, cancer specific Quantum dots provide a new tool to enable non-invasive visualization of disease-specific molecular and tissue changes with subcellular spatial resolution [40]. Nanotechnology is in a unique position to transform cancer diagnostics and to produce a new generation of fluorescent markers and medical imaging techniques with higher sensitivity and precision of recognition [41].

8. Conclusions

Research in nano-medicine will allow for a better understanding of the functioning of the human body at molecular and nano-metric level and it will thus give us the possibility to intervene better at pre-symptomatic, acute or chronic stage of illnesses. There is controversy generated by the possible toxic health effects of nano-particles. Immobilized nanostructures inside or on surfaces of medical devices, such as surgical implants, are expected to pose a minimal risk provided they remain fixed. While nanotechnology-based products are already in use, further research is needed on the potential risks to human health that could be associated with this new technology.

Developing nanotechnologies are being pursued for general cellular processes such as ubiquitous signaling pathways that may benefit numerous physiological systems, as well as being targeted toward the particular challenges of specific disorders such as diabetes mellitus, Cancer, alzheimer's, arteriosclerosis, and AIDS. Ultimately, every patho-physiological process has a molecular origin, and it is from this basic fact that the tremendous potential of nanotechnology applications to human health and disease arises.

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