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Promise of Nanotechnology in Biomedical Applications

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The development of nanotechnology has invigorated material sciences research such that innovative nanoscale platforms are being rapidly designed to tackle the classical challenges of biomedical sciences. An enhanced theoretical understanding of quantum physics and tunable synthetic methodologiesis driving design of smart nanoscale structures that bridge the gap between the macroscopic world and molecular-level detail. The interdisciplinary nature of nanotechnology is paving the way for further progress in cellular biology and clinical and basic sciences. Generally, nanoscale agents have structural features ranging from 1 to 100 nm, a length regime where unique particle properties can be harnessed for various applications. For example, in spherical nanoscale objects the surface area-to-volume ratio decreases with increasing sphere radius, a property that leads to high internal packaging capacity that is currently being utilized for therapeutic and *in vivo* imaging applications [1]. In oncology, the use of nanotechnology based drug-delivery systems is proving to be superior to traditional chemotherapeutic agents as nanoparticles can be tuned for better bioavailability and favorable pharmacokinetics, leading to reduced toxicity and enhanced efficacy [2]. Additionally, nanoparticles have opened up new avenues for cancer therapy, such as photodynamic and hyperthermia treatments [3]. One of the quests in cancer diagnostics is to detect cancer cells sensitively and selectively at very early stages of the disease. Nanoparticles are attractive probes for accomplishing these goals [4]. Nanoparticles can be designed to be multifunctional and as such are being diversely used as multimodal, targeted platforms, bringing us closer to the reality of personalized medicine [5,6].

When applied to biological systems, the structure-activity relationship of nanoparticles with target moieties is critical and is influenced by size, shape and surface chemistry of the particles [7,8]. Due to the wide variety of nanoparticle compositions, both organic and inorganic, that are being produced in research laboratories around the world, generalizations of specific structure-activity results are not feasible. However, rigorous *in vitro* and *in vivo* evaluation of nanoparticle systems is needed to validate the efficacy and safety for human use. In a recent issue of Chemical Society Reviews, several key developments and topics relevant to the field of nanomedicine are discussed [9]. Smooth translation of new nanoparticle based therapeutic and imaging agents from bench top to human use is a learning curve for both the research labs and regulatory agencies like the U.S. Food and Drug Administration (FDA). FDA has provided specialized resources for nanotechnology based drugs and has also formed a Nanotechnology Task Force to determine regulatory approaches to encourage development and translation of innovative, safe and effective materials (http://www.fda.gov). Alternately, successful applicants should openly share the lessons learned with the nanoparticle research community so that researchers can adjust to the regulatory demands ahead of time.

The promise of nanotechnology is robust, but a cautioned approach should be practiced as the long-term impact of these materials on the society as a whole is yet to be determined.

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