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Nanomaterials in Biomedicine

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Nowadays, nanomaterials have become an emerging field that has shown great promise in the development of novel diagnostic, imaging and therapeutic agents for a variety of diseases, including cancer, due to their nanoscale size effects and increased surface area [1]. In comparison to their larger counterparts, nanomaterials have unique physicochemical and biological properties including size, shape, chemical composition, surface structure and charge, aggregation and agglomeration, and solubility which can affect their interactions with biomolecules and cells [2]. Nanoparticles (NPs) with size-tunable light emission have demonstrated an impressive potential as high-efficiency delivery transporters for biomolecules into cells, being used to produce exceptional images of tumor sites [3]. Moreover, NPs delivery system has been widely applied in pharmaceutical field to enhance absorption of bioactive compounds since they can interact with several phytochemicals by hydrogen bonds and hydrophobic interactions to encapsulate these phytochemicals in NPs and thus enhance aqueous solubility of the chemicals [4]. Moreover, NPs also can prevent against oxidation/degradation of the phytochemicals encapsulated in the gastrointestinal tract and can be taken directly up by epithelial cells in the small intestine resulting in the increase of absorption and bioavailability of phytochemicals. In general, there are two specific fields of utilization of intrinsically active NPs as pharmacologic agents including oxidative-related pathologies and cancer. On the other hand, Redox active NPs have been shown to ameliorate many clinically relevant pathological disorders that implicate oxidative stress, reducing the oxidative burden and alleviating many important symptoms. Such NPs act either in a catalytic way resembling the action of antioxidant enzymes such as catalase and superoxide dismutase, or as activating surfaces to facilitate reactions between the aqueous environment and the reactive oxygen species present at high level in the pathological tissues [5].

In anticancer therapies, metal and metal oxide NPs are being used experimentally to directly kill tumor cells e.g., allowing extremely localized thermo-ablation by transforming applied magnetic fields into strong hyperthermia, or performing efficient photodynamic therapies able to reach even the internal tissues by transforming a penetrating infrared radiation into visible light inside the tumor [6]. Moreover, NPs made of heavy atoms are able to react to irradiation producing cytocidal reactive oxygen species, consequently increasing the pro-apoptotic effects of radiotherapies once correctly localized at the site of the tumor.

One of the most important applications of NPs in medicine is the controlled drug release. Sustained (or continuous) release drug delivery system involves NPs that release drugs at a controlled rate, by diffusion or degrada-

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tion of the structure of the nanoparticle over time [7]. Other nano drug delivery approaches are focused on crossing certain physical barriers, such as the blood-brain barrier, or on finding alternative and acceptable routes for the delivery of a new generation of drugs based on proteins to be used through the gastrointestinal tract and prevent degradation. However, a successful system for the transfer of drugs needs to demonstrate optimal drug loading and good qualities of its release, a long duration in storage and low toxicity.

On the other hand, carbon-based nanostructured materials, such as graphene, carbon nanotubes (CNTs) and nanodiamonds (NDs), have demonstrated to be highly promising materials for designing and fabricating nanoelectrodes and substrates for cell growth, by virtue of their peerless optical, electrical, thermal and mechanical properties [8]. Nanoscience and nanotechnology are the basis of innovative and unprecedented techniques, offering unimaginable potential for the benefit of patients and new markets, companies that manufacture pharmaceuticals, and drug delivery systems.

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