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Trends in Biomedical Nanotechnology

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The nanotechnology, as defined by the US National Nanotechnology Initiative (NNI), is fabrication of materials with at least one dimension in 1-100 nm range [1]. The field of nanotechnology has generated tremendous excitement because these materials exhibit fundamental properties that are significantly different from that of bulk material, and are attributable to their small size (≤100 nm). For instance, quantum dots are nanoparticles (2-10 nm) of semi-conducting materials, usually selenides or sulfides of metals like zinc and cadmium. The quantum dots, owing to their nano size, exhibit superior signal brightness, size dependent emission of light, which, is resistant to photo bleaching, contrary to organic fluorescent dyes. Thus by controlling the size of quantum dots, it is possible to control the wavelength of emission for these nanomaterials. The size-based tunable light emission and resistance to photo bleaching observed in quantum dots is attributed to their nano size, and is not present in bulk materials. The main aim of nanotechnology is to take advantage of these unique properties in fabricating novel materials and devices, or developing unique applications.

The major thrust of biomedical nanotechnology is to apply the benefits of nanotechnology to healthcare (e.g., imaging and diagnostics; nanodrugs; drug delivery; prostheses; and implants; etc.) [2,3]. Nanotechnology has been earlier used to improve drug properties. For example, pacliaxel (taxol), an anticancer drug, which is used to treat primary epithelial ovarian carcinoma, breast, colon, and lung cancers, exhibits low water solubility and, therefore, poor bioavailability. Therefore, it was formulated in Chremophor EL (polyethoxylated castor oil), which has been implicated in several drug associated toxicities. To overcome these shortcomings associated with the use of Cremophor, paclitaxel bound to albumin nanoparticles (Abraxane) were developed for clinical use. There is a huge interest in employing nanotechnology for cancer drug delivery. The interest in cancer drug delivery stems from the fact that the nanoparticles passively target tumors by a process called enhanced permeability and retention (EPR) effect, as elucidated by Maeda and coworkers [4-6]. It occurs because the tight junctions between endothelial cells of microvessels measure around 2 nm (6 nm in kidney, liver, and spleen), whereas the pore size of tumor microvessels varies from 100 to 1200 nm. Therefore, nanoparticles of appropriate size are able to extravasate into tumors, and not normal tissues, where they are retained because of slow venous return and poor lymphatic drainage. Another advantage is the fact that nanoparticles possess large surface area, which can be exploited to graft various types of functional groups on to the nanoparticles. For instance, it is possible to graft diagnostics and therapeutic moieties on to the same nanoparticles to combine diagnostics and therapy (theranostics) into one delivery platform [2,3].

Despite the promises that biomedical nanotechnology holds for healthcare, there is a concern, in general about its safety and, in particular, the possibility of causing unforeseen adverse effects [2,3]. The concern that the nanotechnology poses a serious health and environmental risks has impeded the field for a very long time. There is a tremendous need to develop methods to characterize nanomaterials and their interaction with biological systems, to monitor the health and environmental risks posed by the nanotechnology.

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