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EDITORIAL

The Holy Grail of medicine: Era of rejuvenation therapy

Nanotechnology and nanoengineering are poised to produce significant scientific and technological advances in diverse fields including medicine and dentistry. This science envisages the design, syntheses, characterization and application of materials and devices whose smallest functional organization in at least one-dimension is on the nanometer scale, ranging from a few to several hundred nanometers. For its application particularly in dentistry, these materials and devices can be designed to interact with cells and tissues at a molecular (subcellular) level with a high degree of functional specificity, thus opening vistas so far unattainable in the field. Nanoengineered materials and devices designed to interact with cells and tissues or carry out biologically specific functions should offer a much greater degree of integration between technology and physiological systems. In turn, this should eventually translate in to novel clinical applications and treatment options. At present, applied nanotechnology to medicine and dentistry is in its infancy, with most of the research at the basic science level as the field attempts to organize itself. As such, viable clinical applications are still years away, but despite this the current pace of development is impressive.

The potential applications of nanotechnology in medicine are vast. This includes targeted drug delivery, nano-enabled therapies, imaging and diagnostics. In cancer research, for example, the ultimate goal is to develop multifunctional nano-scale devices that act as both imaging agent and anticancer therapy. One of the most highly publicized areas of nanomedicine research involves gold nanoshells to detect and treat cancerous tumors. Here is a case where detection and therapy overlap. Nanoshells are particles of silica (glass) completely coated with gold, made up of a few million atoms. They can be produced in a range of sizes, with diameters smaller than 100 nm to as large as several hundred nanometers. When injected in to the blood stream, they naturally congregate at the tumor sites and therefore no additional targeting is necessary. In order to feed their growth, tumors create many blood vessels (neoangiogenesis) very quickly, so the vessels are often defective, allowing the nanoshells to slip through vascular ‘‘leaks’’ and gain access to the tumor. Detecting and targeting tumors by exploiting their surrounding vascular defects is known as ‘‘enhanced permeability and retention’’ or EPR effect. A nanoshell captures light and focuses it around itself. By manipulating the size of the nanoshells, it is possible to change the way they absorb light. The goal in cancer detection and therapy is to ‘‘tune’’ the nanoshells to interact with near-infrared light (NIR). When exposed to NIR, the nanoshells act like ‘‘a swarm of fire flies’’ and light up the area where they have congregated (i.e., tumor sites). Once the nanoshells have completed their imaging tasks, they become therapeutic agents. The area around the nanoshells heats up and the tumor ‘‘cooks’’ until it is ablated. These claims will have to be closely scrutinized, as nanoshells will likely take up permanent residence in the body and it is not clear how or if the body could excrete them.

‘‘Quantum dots’’ are semiconductor nanoparticles that have unique optical and electrical properties. When exposed to light, these nanoparticles emit distinctly different colors depending on their size (the smaller the quantum dots, the brighter the color). Although fluorescent dyes have been used for decades in the human body for biomedical imaging (to track the effects of cancer drugs, for instance), they are often imprecise and only visible for short time periods. Fluorescent quantum dots will provide a brighter, more precise and longer lasting alternative. Quantum dots can be injected in to cells or attached to proteins in order to track, label or identify specific biomolecules and that they offer the ‘‘ultimate detection sensitivity’’. Quantum dots can stay inside cells for weeks or months, but virtually nothing is known about how these nanoparticles metabolize inside the body or their routes of excretion.

Nanotechnology will play a key role in tissue engineering because it operates on the molecular scale and is capable of integrating both biological and non-biological materials. Researchers are using self-assembling nanostructures to create artificial collagen (main protein component of bones, skin, teeth and tendons). Because it is a major structural component of the tissues and organs, it is hoped that nano-structured artificial collagen as the three-dimensional scaffolding is needed to encourage cell regeneration for growing specific cells, tissues and organs. Nano-scale materials are being used to develop

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synthetic bone replacement materials with improved durability, biocompatibility and strength. Technology to produce synthetic bone replacement material that could be used for bone grafting or for bioactive coatings on artificial joints such as hip and knee replacements and dental implants are being tested.

As it stands now, the majority of commercial nanoparticle applications in medicine are geared towards drug delivery. There are some developments in directing and remotely controlling the functions of nano-probes, for example, driving magnetic nanoparticles to the tumor and then making them either to release the drug load or just heating them in order to destroy the surrounding tissue. The major trend in further development of nano-materials is to make them multifunctional and controllable by external signals or by local environment thus essentially turning them in to nano-devices. Ultimately, every patho-physiological process has a molecular origin, and it is from this basic fact that the tremendous potential of nanotechnology applications to medicine and dentistry arises.

Further reading

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Professor R. Rajendran
Division of Oral Pathology,
Department of Oral Medicine and Diagnostic Sciences,
College of Dentistry,
King Saud University,
Riyadh 11545, Saudi Arabia
E-mail address: rrajendran_r@yahoo.co.in