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Nano-Bio-Technology Excellence In Health CareNano-Bio-Technology Excellence In Health Care: A Review

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Abstract

Nanotechnology refers to the study and design of systems at the scale of the atom, or the nanoscale. Nanoscience is the study of nanoscale material with novel properties and function. Nanotechnology, based on the manipulation, control, and integration of atoms and molecules to form materials, structures, devices, and systems at the nanoscale, is the application of nanoscience, especially to industry and commercial objectives. Nanoscale bioengineering focuses on the development of a fundamental understanding of nanobiostructures and processes, nanobiotechnology, and techniques for a broad range of applications in biomaterials, biosystem based electronics and health. This discipline provides understanding of the relationships among chemical composition, single molecule behavior and nanoscale level of biological functioning. Some commonly known molecular nano scale structures that occur in living things are amino acids (0.42-0.67nm), nucleotides(0.81-0.87nm), monosaccharide (1 nm), heme (1 nm) and phosphatidylcholine (2-3 nm). Biomimetics is the study of synthetic structures that mimic or imitate structures found in biological systems. Nature has capitalized on the physical properties of nanoscale biologic materials. Materials and systems at nano scale operate to perform the vital functions required by living things, so it is no wonder that scientists are attempting to mimic nature's accomplishments. We are reviewing and discussing nanotechnology in this article.

REVIEW

On March 10th 1997, the issue of Business Week stated that the biology will define scientific progress in the 21st century and will be called “Biotech Century” whereas nanotechnology has been called “the manufacturing technology of the 21st century.” Nanotechnology refers to the study and design of systems at the scale of the atom, or the nanoscale. Nanoscale exists between 1 and 100nm. In the more sense, materials with at least one dimension below 1000nm but greater than 1nm are considered as nanoscale materials. A nanometer is one billionth of a meter, too small to be seen with conventional microscope. It is at this scale –about 100 nanometers or less-that biological molecules and structure s inside the living cells operate. Nanoscience is the study of nanoscale material with novel properties and function. Nanotechnology, based on the manipulation, control, and integration of atoms and molecules to form materials, structures, devices, and systems at the nanoscale, is the application of nanoscience, especially to industry and commercial objectives. Nanoscale bioengineering focuses on the development of a fundamental understanding of nanobiostructures and processes, nanobiotechnology, and techniques for a broad range of applications in biomaterials, biosystem based electronics and health. This discipline provides understanding of the relationships among chemical composition, single molecule behavior and nanoscale level of biological functioning. Some commonly known molecular nano scale structures that occur in living things are amino acids (0.42-0.67nm), nucleotides(0.81-0.87nm), monosaccharide (1 nm), heme (1 nm) and phosphatidylcholine (2-3 nm). Biomimetics is the study of synthetic structures that mimic or imitate structures found in biological systems. Nature has capitalized on the physical properties of nanoscale biologic materials. Materials and systems at nano scale operate to perform the vital functions required by living things, so it is no wonder that scientists are attempting to mimic nature's accomplishments.

At the most basic level, the manufacturing is actually the rearranging of individual molecules and atoms into complex “molecular machines.”

Most disease begins at the cellular and molecular levels. However, the tools of modern medicine are too large and cumbersome to reach disease at this stage. With nanotechnology, we will be able to have computer-controlled machines that are much smaller than a human cell that can address disease at the cellular and molecular levels.

No one is sure how long these innovations will take--it could be years or decades--but at some point nanotechnology will likely allow us to remove obstructions in the circulatory system, kill cancer cells, repair organs, create artificial mitochondrion and view tissue samples with extraordinary detail.

Within a couple of years, scientists hope to use nanotechnology to detect the location of viruses in the body. The process would involve injecting magnetic nanoparticles into the bloodstream and would potentially allow more precise virus treatments to be developed. Although it is largely still in the experimental stages, nanotechnology is growing fast.

The next step in the nanotechnology adventure is in the realm of nanomedicine, where nanotechnology is expected to contribute to significant developments improving the health of human beings. Nanomedicine is an offshoot of nanotechnology, which refers to a highly specific medical intervention at the molecular scale for curing disease, or repairing damaged tissue, such as bone, muscle, or nerve.

Nanomedicine may be defined as the monitoring, repair, construction and control of human biological system at the molecular level, using engineered nanodevices and nanostructures. The realms of nanomedicine includes delivery systems for drug and gene therapies, body or organ imaging and labeling with nanostructured materials, surgical tools, nanoprobes aiding diagnostic procedures, molecular recognition, smart nanosensors with communication capability, and synthetic implantable therapeutic devices.

DNA Nanowire is the best molecular electronic device ever produced on the earth because DNA can store, process and provide information for growth and maintenance of living system. All living species are as a result of single cell produced during reproduction. In most of the cases this single cell does not have most of the materials required for fabricating a living system but contains all the information and processing capability.

Microelectromechanical systems (MEMS) include all those devices, which have dimensions in microns and has both electronic and mechanical components together. It is an enabling technology that combines the processing capability of electronics with the work capacity of mechanics to achieve functions attainable. Biomems takes advantage of interfacing MEMS components with functional biomolecules to enhance their capability and performance for host of engineering and healthcare applications. Some of the applications of biomems include DNA analysis tools called micro arrays and the camera pill, a swallowable capsule with a tiny camera that provides diagnostic images of the small intestine. The latest applications such as therapeutic microchips and DNA repair are moving in that direction. The ultimate goal of this technology is to create fantastic therapeutic chips that are able to go inside the body, feel, diagnose, sense and repair. Such a device is no more inside the realm of science fiction.

Fast advancement in digital signal processing, microelectronics, battery technology have produced devices that have contribute significantly to the quality of life and communication abilities of persons with hearing impairment. The cochlear implants which is surgically implanted and provide hearing sensation to the individuals with profound hearing problems and who cannot be benefited with hearing aids. Patients who use bilateral cochlear implants show improve understanding of speech in noise, better localization of sound ability and improved sound quality[1,2,3].

Middle ear implants have overcome the disadvantages of acoustic hearing aids like ear canal occlusion, acoustic feedback, sound distortion and cosmesis. MEI delivers sound by driving the middle ear ossicles mechanically, rather than acoustically, through either electromagnetic or piezoelectric transducers. These implants show an average threshold improvement of 10dB from 500-4000 Hz. At 6000Hz the gain is about 20dB compared with conventional fitted acoustic hearing aids.

Tinnitus is a disorder that has remained refractory to treatment. The symptom of tinnitus results from myriad of pathologies. Somatic sounds produced in the vicinity of the cochlea will elicit the perception of the tinnitus. In sensorineural tinnitus the symptoms arise from auditory system itself. For the majority of the tinnitus patients treatment is aimed at modulating the patient's response to the tinnitus, rather that treating the tinnitus itself. An implantable device that can provide chronic electrical stimulation in the middle ear in closed proximity to the cochlea offers the best solution for suppressing sensorineural tinnitus with out jeopardizing residual hearing. Recently developed bion microstimulator, is an attractive method for implementing the solution[4]. The bion, which is a miniature, self contained, rechargeable neurostimulator, can be implanted behind the ear with an electrode running subcutaneously to the middle ear to stimulate the round window or promontory with charge-balanced AC stimulation.

Tissue engineering is related to restoration of tissue structure and function by using the living cells. The process consists of cell isolation and expansion and reimplantation with or without a scaffold material, which can induce, surrounding cells to tissue restoration. The scaffolds can be porous prefabricated materials like polyglycolic acid (PGA), polylactic acid (PLA) and their copolymers polylactic-co-glycolic acid (PLGA) like degradable sutures. Another example is in situ forming scaffolds, fibrin glue [5,6], which is a hydrogel material that are often used as cell delivery vehicles for tissue regeneration.

Tissue fusion shows great promise in creating the ideal wound closure. Modern adhesives achieve faster and better wound closure [7]. The concept is not new and the use of fibrin dates back to 100 years. Other adhesive and sealant materials, collagen based, are biodegradable forms a collagen plug to form a coagulum at the site of vascular bleed. Two approved devices are VasoSeal and Angio-Seal. Photochemical activation, laser tissue welding and nonlaser heat-mediated fusion are energy based wound closure methods.

From an otolaryngologic perspective most head and neck applications would involve chondrocytes and osteoblasts along with some type of scaffold material because of the importance of the initial shape and support. In the 1950s, European researchers discovered that when titanium is exposed to air, it develops an oxide layer that forms an active biological field that promotes living tissue to grow and bone permanently with the titanium [8]. This process, called osseointegration, was first used in dental implants. The same process has been adapted and used to develop a bone-anchored hearing aid (BAHA), a system for delivering acoustic information to the inner ear through direct bone conduction.

Applications and future directions of bioengineering tissue in otolaryngology are Auricular reconstruction. From either congenital or traumatic causes requires that the implanted tissue maintain shape over time (structural fidelity) and closely mimic the biomechanical properties of elastic cartilage. Currently, costal (rib) cartilage provides a readily available source of hyaline cartilage that can be carved, shaped, and implanted for creation of a neoauricle.

In medical therapy, a substantial application field for nanotechnology is the controlled and targeted transport of drugs (“drug delivery”). The use of nanoscale transportation vehicles should make it possible to achieve, that the active drugs affect selectively the targeted regions of the human body only, minimizing unwanted side effects.

Such transportation systems could be realized, in principle, from nanoscale cage molecules (e.g. liposome, fullerenes or other cage molecules such as dendrimers) or by coupling with nanoparticles. The goal here is to carry the active drugs selectively to the targeted cells, by means of nanoparticles with specific surface functionalization. Nanoparticles are small enough to penetrate cell membranes and overcome physiological barriers (e.g. blood-brain barrier) in the organism. Furthermore, nanoparticles and nanoscale suspensions improve the solubility and bio-availability of drugs and allow the application of drugs which are, so far, not applicable.

By the coupling of drugs with nanoparticles, less burdening application procedures can be realized like inhalation instead of infusions, for example. By functionalised nanostructured coating of the drug particles, the deposition speed can be controlled and smaller doses can be applied reducing unwanted side effects.

Cancer is a complex disease that shows great variability from patient to patient. The isolation of one or a few indicators of suspected pathology would still require judgment on how to proceed with the therapy. Future aids to such judgment will rely on greater integration of diagnostic tools. Such integration will need models of both healthy and malignant tissue that recognize the way that tissue functions as a complex, dynamic system. Systems approach is progressing at the cellular level as signaling network and gene regulation processes because better understood [9,10,11]. Corresponding approaches at the tissue level will be needed to reorganize combinations of events occurring in might be developed to measure the collective response of populations of cells to stress experienced by mucosal tissue. In this way, detection of local molecular and structural abnormalities might be placed in a context that allows earlier and more reliable prognosis and choice of therapy.

Neurofibromatosis Type 2 is a genetic condition with bilateral benign tumor on the vestibular branch of auditory nerve. The tumor can be removed surgically but auditory nerve is often severed during surgery resulting in bilateral deafness. So these patients are not benefited with cochlear implant, as the patient is not having functioning auditory nerve. A custom electrode named Auditory Brain stem implant (ABI) was fabricated which was placed in the lateral recess of fourth ventricle[12]. The patients can detect sounds and can lip-read although they have poorer speech perception ability.

Optical method provides a wide range of diagnostic tools for discriminating cancerous tissue from a healthy tissue. The most widely developed approaches use scattering and florescence measurements together to detect changes in the tissue structure and composition. Infrared or Raman spectroscopy can potentially provide specific information about protein, lipids, sugars, and DNA molecules and their environment. A goal is to relate these observations to underlying molecular changes that are thought to be responsible for cancer progression. Now in vivo microscopes and molecular tagging techniques promise to help make such molecular identifications possible in a routine clinical setting. Measurements of other physical properties can provide complimentary information about tissue structure and function. Infra red light is typically absorbed and re-radiated as a result of changes in the irrational energy of the molecular bonds. Quantum theory shows that the energy exchanges and consequently the wavelengths of photons absorbed or emitted are restricted to discrete values (quanta) that depend on the particular molecular bond and its environment. Infrared spectroscopy can thus be a sensitive indicator of molecular species and is a common tool in the analytical chemistry laboratory.

Successful use of infrared spectroscopy in vivo to identify molecular changes in tissue is subject to considerations similar to those governing the use of fluorescence.

Portable brain functional imaging using infrared light is new to the field is the use of near-infrared spectroscopy [NIRS] is possible because biological tissue is transparent to light in the near –infrared range between 700 and 1000 nm. Water and hemoglobin absorption are relatively small within this wavelength region. NIRS, therefore, allows the non invasive recording of cortical activity. Four types of activity –related signals can be recorded non-invisibly: (1) change in hemoglobin oxygenation, (2) change in blood volume, (3) change in CO2 oxidation, and (4) fast optical signals presumably related to change in light scattering.

CT had its infancy in 1970s and the first application was in head scanning. CT evolved into faster axial scanning, and now helical multi-detector CT [MDCT] has variety of uses and indications like thoracic and abdominal scanning and also has advantage for head and neck imaging, base of skull, temporal bone, complex facial fractures, spine trauma, angiograms and location of neoplasm, lymphadenopathy, infiltration or spread of disease involving the vasculature, small lesions of vocal card and during the procedure the patient phonates “E” for 10 seconds. The multiple detectors allow the acquisition of several images at one time. The information from multiple detectors can be combined to produce thicker section. The images can be obtained in helical and axial mode and can be reformatted in any plane with special resolution.

Several studies have evaluated Lymphadenopathy with dynamic contrast enhanced MRI with the hope of distinguishing metastatic nodes from reactive or lymphomatous nodes.

Dynamic contrast-enhanced MRI has also been used to evaluate pleomorphic adenomas and other neoplasms of the salivary glands.

Typical MRI demonstrates a predilection for intermediate signal intensity on T1-weighted images, heterogeneous signal intensity on T2-weighted images, and heterogeneous enhancement.

Multiple new MR techniques have joined T1-and T2-weighted imaging in the evaluation of head and neck diseases. Some of the new techniques in development are inversion recovery MRI, dynamic contrast-enhanced MRI, MR spectroscopy, the use of iron oxide particles for functional MRI to characterize adenopathy, and apparent diffusion coefficient mapping (ADC) of the parotid gland and can help delineate tumors and Lymphadenopathy for easier identification and measurement.

Positron emission topography [PET] is a quantitative imaging modality that can assess biological characteristics of the tissue, including metabolism, proliferation, and blood flow. The information obtained by PET is essential independent of tumor location and lesion size. PET has been used in the clinic for the assessment of tumor aggressiveness[13], for treatment evaluation[14], and for detection of recurrent disease[15] in patients with head and neck cancer. Because additional information provided by PET, the current trend in radiotherapy is to incorporate PET imaging data to reduce or eliminate geographical misses and help guide dose intensification to the most metabolically active areas within the neoplasm.

Diffuse reflection spectroscopy to accentuating subtle changes in oral lesions is to measure quantitatively the spectroscopic composition of light reflected from the tissue.

The multifunctional nanoparticle QD probe is developed for targeting and imaging cancer in live animals. The researchers managed to encapsulate luminescent QDs with a polymer and link them to "tumor-targeting ligands and drug delivery functionalities"[16]. Research continues to investigate the metabolic effects and clearance of the QD probes injected into the live animals.

Now micro-cantilever based (200x50x0.5 micron) diagnostic kits are utilizing anti-body/anti-gene reactions for tuberculoses. Cost of these disposable micro-diagnostic kits is affordable per diagnosis and time period of only few minutes in comparison to presently used culture techniques, which takes about few weeks time and costing more than 200 times. The amount of blood sample and reagents is also reducing this techniques by a factor of 100-1000 i.e. only few microlitre. This concept can be extended to large number of diseases and monitoring toxins in environment including drinking water and food.

Port-wine satins are benign vascular birth marks consisting of superficial and deep dilated capillaries in the skin resulting in reddish to purplish discoloration. They are present in 0.3% to 0.5% of newborns, initially light in colour, darken with age as capillaries continue to dilate, and can later progress to a raised and nodular surface. PWSs can cause significant psychologic trauma and often lead to reduction in the quality of life. Treatment of PWS has included skin grafting, ionizing radiation, cryosurgery, tattooing, dermabrasion and laser treatment. Currently, lasers provide the treatment of choice for more PWS patients.

Photodynamic therapy has much interest as an alternative to surgery or radiotherapy for the destruction of high-grade dysphasia and early carcinoma in the esophagus. Image-guided radiotherapy (IMRT) has compelled the radiotherapy community to pursue greater precision. Although there has not been extensive use of image-guided radiotherapy (IGRT) in head and neck treatment, this modality commands attention for the potential that it promises in localization and reproducibility or patient treatments.

Interstitial brachytheapy consists of Low dose rate LDR and high-dose-rate HDR brachytherapy for the treatment of head and neck cancers. At present seeds that contain the radionuclide of Iodine–125 or Palladium-103 are routinely used in permanent interstitial implants[17].The I^{125} seed has a long half life 59.4 days where as Pd^{103} seed has a shorter half life 16.99 days. Pd seeds are better for slow growing tumors where as ^{125}I seeds are better for slow growing tumors. LDRIB is effective modality for the treatment of oropharyngeal carcinoma. Excellent local control (65%-89%) has been reported using this modality. With LDRIB, however, radiation exposure to medical personnel is unavoidable, even when an after loading device is used. To eliminate this concern, Nose et al[18] use HDR interstitial brachytherapy (HDRIB), which consists of implanting plastic tubes in the pharyngeal cavity that subsequently receives ^{192}I sources by manual after loading. Between 1993 and 2003, they used HDRIB plus external beam radiotherapy to treat 83 patients with oropharyngeal squamous cell carcinomas. From their 10-year experience, they concluded that HDRIB could achieve excellent local control and acceptable rates of complication, equivalent to the results reported for LDRIB series. Because of the advantage of radioprotection, HDRIB may replace LDRIB in the treatment of head and neck cancer.

Stereotactic radio surgery (SRS) offers the merits of the mechanical accuracy of stereotaxy – high and homogeneous dose distribution within a small target volume, and the rapid dose fall-off in the surrounding normal tissues. SRS has been successful in treating small brain tumors with high accuracy. The gamma knife and linear accelerator are tow of the most common machines for photon beam radiosurgery. The same SRS equipment used for intracranial lesions can treat head and neck lesions as long as the head frame is placed low enough on the skull to permit CT scanning and MRI through both the stereotaxic fiducial device and skull base in at least one axial plane[19].

Another project is aimed at developing a shoe insole equipped with a wireless temperature monitoring system that provides feedback to the patient about a pattern of activities that may lead to ulceration. This insole could have the potential for reducing amputation in diabetic patients. Using an insole temperature monitoring device and prescriptive self-care will have significantly decreased risk over time of foot ulceration, fewer infections and cases of osteomyelitis as well as decreased healing time for foot ulcers.

Emerging technologies have demonstrated to improve surgical time, decrease postoperative pain and reduce tissue damage and unwanted side effects. These alternative surgical techniques include bipolar scissors, coblation and harmonic scalpels.

Bipolar scissor has the ability to dissect with or without cautery. The bipolar scissors used in different surgeries such as tonsillectomy, micro vascular free flap surgery without using the tourniquet and superficial parotid surgery etc. with significantly less operating time but only complication mentioned in the literature is superficial burn.

Coblation originally designed for cartilage repair during arthroscopy surgery. Electrodes at the tip of the coablation probe serve as a source of radio frequency energy which excites the saline solution thereby creating a field of electrically active sodium ions that able to dissociate the tissue molecular bonds.(electro-dissociation procedure)as there is steady flow of saline from the probe low tissue temperature is generated 40-70°C as compared to electro cautery which produces 400°C –600°C.the procedure is used for tonsillectomy, turbinectomy and palatal reduction.

Harmonic scalpel leads to ultrasonic coagulation results in denatured protein which coatpts and temponades the vessels. Its use is in laproscopic abdominal surgery, tonsillectomy and thyroid surgery, excision of cancer of tongue and soft palate submandibular gland excision parotidectomy[20] inferior turbinate alteration, rhinophyoma. Temperature controlled radio frequency ablation (TCRFA) is widely used in sleep apnea disorders, arterial fibrillation, trigeminal neuralgia, prostatic hypertrophy, liver tumors.

Researchers have developed a fabric made from compounds used by the body to clot blood that becomes a “natural bandage.” The nano-fiber mat is spun from strands of fibrinogen, which are 1,000 times thinner than human hair, and could be placed on a wound and never taken off, as eventually it would be absorbed by the body.

The mat would be useful for a variety of purposes including minor cuts, battlefield wounds and bleeding in surgeries, where surgeons could apply the mat and leave it there.

Using the same technique that they used for the mats, synthetic blood vessels from collagen have also been developed which are six times smaller than those available.

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