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BIOCHEMICAL INTEGRATION OF CHEMICALLY MODIFIED CARBON NANOTUBES

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Abstract

Carbon nanotubes (CNTs) have attracted growing interest in recent years for their small size, ordered structure, and distinctive surface and atomic configurations that enable applications across biomedicine and materials science. The objective of this study is to synthesize current knowledge on CNTs, how they are defined, classified, arranged, and synthesized; their unique properties; and their applications and risks with emphasis on drug delivery and broader biomedical uses. Methodologically, the paper conducts a literature-based review of CNT properties and uses, including their roles as carriers for therapeutic molecules (e.g., peptides), biosensors, and components in molecular electronics and composite materials, as well as hazards, regulatory considerations, and medical status. Key findings indicate that CNTs are promising, biocompatible, and supportive materials for transporting therapeutics owing to their internal cavity and ease of coating with biocompatible chemicals; they can be readily taken up by cell membranes and have been reported to deliver drugs directly to cancer cells. Beyond biomedicine, CNTs' structural and surface features support their application as biosensors and in molecular electronics and composite formulations. The study concludes that CNTs offer substantial potential for targeted drug delivery and multimodal biomedical uses while requiring careful consideration of hazards and regulatory frameworks. The contribution and implication are a consolidated overview that highlights largely untapped opportunities for CNTs in biological research and clinical translation alongside the need for systematic evaluation of safety and oversight.

Keywords: Carbon Nanotubes; Drug Delivery; Biomedicine; Biosensors; Molecular Electronics; Nanocomposite Materials; Functionalization; Toxicity and Regulation

Introduction

The modern healthcare environment is the one that is marked by the constant urge to develop constantly smaller, more multipurpose, effective, cost-efficient and bio-compatible recovering systems and gadgets. Nanotechnology is an interdisciplinary subject that falls on the border of physics, electronics, materials science, engineering and biology where properties are studied and used at an atomic scale (i.e. 0.1 100 nm). The reference to the Greek equivalent of the word dwarf means that the term nanotechnology is aimed at highlighting the microscopic nature of the materials to be analysed. Its most important composite units are nanoparticles, nanoemulsions, dendrimers, quantum dots and carbon nanotubes (Sahoo and Labhasetwar, 2003). One of the most promising types of a nanovector is the carbon nanotubes (CNTs) that can be used to subvert various clinical applications (Sarwar *et al.*, 2010). Due to their becoming profile of utility, CNTs attract significant academic and commercial attention and more than several thousand peer-reviewed articles are published in this area every year. CNTs have been advocated as convenient nanocarriers in nanomedicine a field of integrative subjects that are grounded upon nanotechnology, biology, and medicine. Their most patentable property lies in: termed release, selective delivery of medicative units to distinct tissue or cellular locales, particularly to malignancies; enhancement of solubility in poor water-soluble medicines; delivery of vaccines; transporting hormones or catalysts; and the development of nanofluidic gadgets on drug delivery. However, the safety aspect is not well-documented and little information is present on the CNT cytotoxicity.

Carbon Nanotubes

Contemporary interest in carbon nanotubes (CNTs) was triggered by the synthesis of buckminsterfullerene (C60) in 1985 and fullerene and other derivatives in 1985 followed by the discovery that C60 could be produced in molecular size, and that it could be shipped to laboratories around the world in 1990 (Hirsch *et al.*, 1990). In 1991, an important milestone was achieved whereby, Sumio Iijima found the existence of CNTs in arc-discharge conditions and consequently, awarded the Benjamin Franklin Medal in Physics in 2002 (Iijima, 1991). Iijima described CNTs as the allotropes of carbon which were folded into a single-walled tubes. After that, arc-discharge technique was used to create multilayered CNTs using graphitic rods. This microstructure of CNT gives properties, which provide important functions in biological applications, primarily those linked with drug delivery, particularly therapeutic drug delivery, and biomedicine (Barnes *et al.*, 2019).

The nanomaterials are hollow cylinders the size of which is determined in nanometers and is composed of monomer units: their assembly provides the formation of a polymeric structure of CNTs. Graphenes can also be regarded as the precursors of CNTs which are seen as folded sheets of graphite. CNTs are visualized by considering their orientation as the graphene sheets stacked in union one against the other, and so, the similarities in the structures and functionality of CNTs with graphene are explained (Kaur *et al.*, 2018; Ali *et al.* 2014). All of this makes them interesting nanomaterials feature-wise, with regards to biomedical and to drug delivery applications: they have a remarkable surface area, high conductivity, excellent tensile strength, and high water-absorptive capacity that may be particularly appealing to biomedical and drug delivery applications, due to the predominance of the cylindrical shape (Boczkowski and Lanone, 2007).

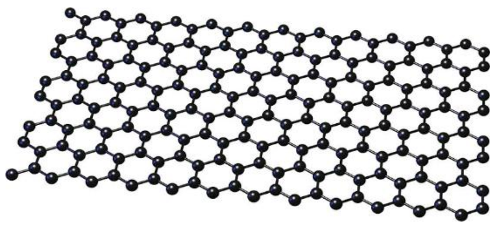

Figure 1: Hexagonal lattice of Graphene Sheet

Source: www.researchgate.net, 2018.

Accessed: May 14, 2021.

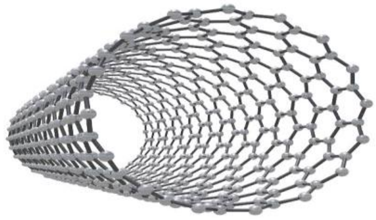

Figure 2: Carbon Nanotube

Source: www.azonano.com, 2019.

Accessed: May 14, 2021.

Classifications and Structures of Carbon Nanotubes

There are two main classifications of CNTs; single walled carbon nanotubes (SWNTs) and multi-walled carbon nanotubes (MWNTs) (Sarwar, *et al.*, 2010). Single-walled nanotubes come into picture when one sheet of graphene is rolled to make a cylinder with a thickness equal to that of an atom. SWNTs normally display three unique types of configurations and these depend on the rolling angle, namely, armchair where a closed armchair path wherein a path encircles the nanotube, zigzag where a donut of zigzag path encircles the circumference and chiral or helical where the nanotube and a mirror image covered by a non-superimposable pair. Similar sizes of CNTs to many well-known biological architectures highlight the significance of their interaction with the living systems (Barnes, Brozena, and Wang, 2019).

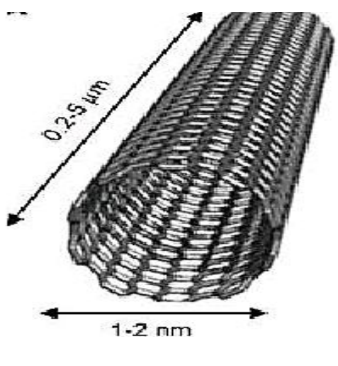

Figure 3: Single-walled Carbon Nanotube

Source: www.researchgate.com, 2009.

Accessed: May 14, 2021.

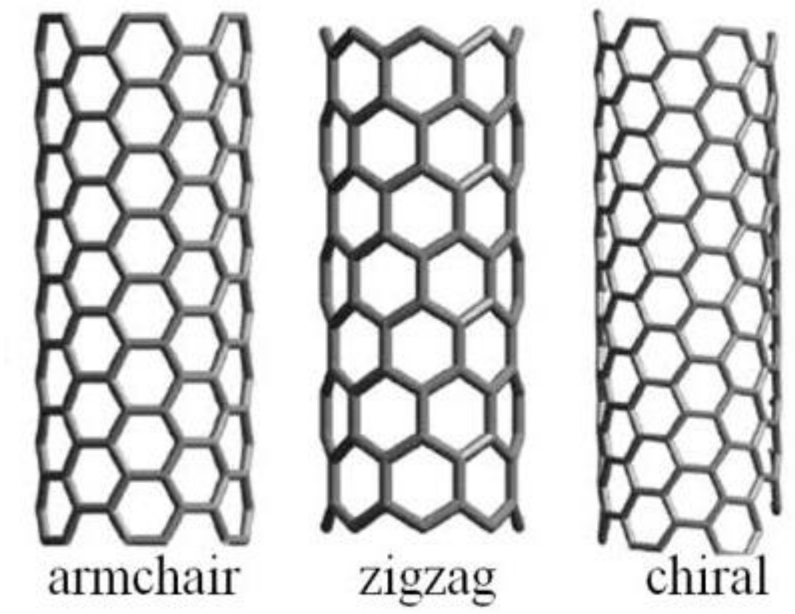

Figure 4: The three classes of the Single-walled Carbon Nanotubes

Source: www.researchgate.net, 2017.

Accessed: May 14, 2021.

Multi-walled nanotubes (MWNTs) are made by two or more graphene sheets and are differentiated according to the layout of sheets. In the first pattern, layers of graphite are placed in concentric cylinders creating so-called Russian-doll structure. The second pattern is the parchment model that entails one sheet of graphite that is rolled like a scroll of parchment or a rolled-up newspaper (Sarwar *et al.*, 2010). The MWNTs are bonded with the help of van der Waals and are generally referred to as the double- and triple-wall carbon nanotubes. Any MWNT is metallic.

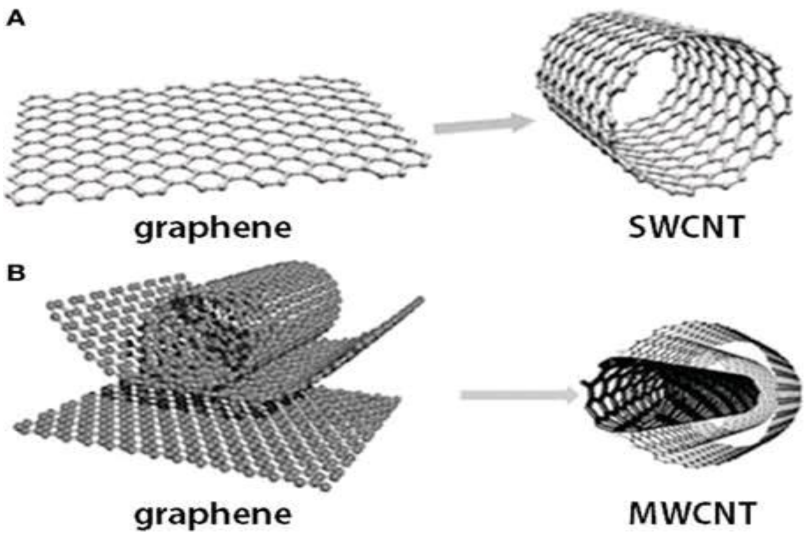

Figure 5: The Single-walled (A) and Multi-walled (A) carbon nanotubes.

Source: International Journal for Research in Applied Science & Engineering Technology (IJRASET), 2018.

Accessed: May 14, 2021.

Properties of Carbon Nanotubes

Mechanical Properties

The carbon nanotubes have the recorded highest tensile strength and elastic modulus of any material exceeding the covalent sp 3 bond of diamond. As an empirical example, the tensile strength of carbon nanotubes is believed to be a hundred times stronger than steel (Akira, 2019). Remarkable also is their elasticity. In spite of large tensile loads, compressive forces, carbon nanotubes bend, twist, kink, and buckle without experiencing structural damage (Ali *et al.*, 2014). When subjected to excessive tensile strain, these tubes experienced plastic deformation (whereby the deformation caused is irreversible).

Electrical Properties

Electrical properties of carbon are an issue of concern that is severely debated (Bockrath, 2006). Single-walled carbon nanotubes (SWNTs) have a ballistic electrical transport meaning that electrons injected at one end of the conductor would appear at the other end with minimal scattering along its path. As a result, SWNTs can be thought of as zero-resistance metals or, indeed superconductors in some senses. Theoretical studies suggest that metallic CNTs may bear electric current densities that are up to ten times higher (around 4,109 A/cm^2) than those maintained by metals like copper, and there is, therefore, the potential to increase the performance of electrical machines (Agnieszka *et al.*, 2014).

Thermal Properties

The thermal conductive properties displayed by carbon nanotubes (CNTs) are extremely high and on the one hand they exhibit high thermal conductivity and on the other hand they can be used as thermal insulators depending on the structural pattern.

Table 1: Comparison between SWNT and MWNT

Properties	SWNTs	MWNTs
Electrical Property	Exhibit high electrical conductivity	Generally, have poor electrical conductivity
Purity	Typically have lower purity levels	Known for their relatively higher purity
Solubility	Dispersible in water and ethanol but prone to rapid re-aggregation after sonication	Quite soluble in water but form slightly translucent dispersions.
Elasticity	Highly flexible and pliable	Have larger elastic moduli and cannot be easily twisted
Layers	Appears as a single layer of graphene	Appears as multi layers of graphene
Synthesis	Catalyst is required for its manufacturing and synthesis	Can be manufactured without catalyst

Source: Sarwar, 2010.

Synthesis of Carbon Nanotubes

Carbon nanotubes (CNTs) can also be produced naturally through the practice of bringing into a controlled condition of flaming carbon black and graphite (Sarwar *et al.*, 2010). The problem with this method is that only nanotubes of strikingly different size, shape, mechanical strength, quality and purity are produced due to the uncontrollability of the combustion environment. Therefore, quite an amount of research has been put on the artificial methods of synthesis. Some of these processes are the Electric Arc Discharge (EAD), Laser Ablation Technique (LA) and Catalytic Chemical Vapor Deposition (CCVD) which are of special interest (Awasthi *et al.*, 2005).

Electric Arc Discharge (EAD) is the process applied to extremely high temperatures of more than 3000 ℃ (Anzar et al., 2020). Graphite electrodes (2 mm diameter) are used as anode and cathode in a 1 mm spacing in the present technique. As soon as such electrodes approach each other quickly in a potential difference of 20-25 V, an electric arc is created. The arc energy is thermally ionized on the carbon atom in the anode and it then forms C^{+} cations thereby forming plasma. These cations are deposited on the cathode and slowly they increase in size to form CNTs. The electrode geometry is set such that 1 mm gap is maintained between them, and adequate cooling of the electrode is necessary to ensure the similar rate of CNTs growth over the cathode. The synthesis of CNT can occur in two different modes including synthesis with and without catalyst precursors. Synthesis of MWNTs normally occurs without catalyst precursors and that SWNTs are synthesized with the presence of catalysts, most often metals like copper nickel, iron, or silver. Its main strength is that the EAD method produces a lot of CNTs. The significant limitation of this approach is associated with the relatively small numbers of possibilities to regulate the chirality of the obtained carbon nanotubes (Ali *et al*., 2014).

Laser Ablation Technique is one process of converting graphite into carbon nanotubes (CNTs) where the starting material is graphite, which is irradiated with a beam of laser light of a certain wavelength, in the presence of a transition-metal catalyst. Two lasers are used simultaneously: one of them splits on the reaction initiation and the second one is then used to make the synthesis of metallic-free CNTs of either single-walled (SWNTs) or multi-walled (MWNTs). This method has its main advantage in the high yields and low metallic contamination; the main limitation of this method is economic aspects of it and long processing times.

A fundamentally different mode of synthesis is processed using Catalytic Chemical Vapor Deposition (CCVD). In this case, reactants are vaporized and experience chemical reduction at a precoated substrate of metal nanoparticles called nickel, cobalt, iron, or a mix of the mentioned. Such nanoparticles can be either fabricated ex situ or in case on the substrate by following reduction of metal salts on a heated surface. The procedure has a temperature range of 600-800 ℃ which favors decomposition of a hydrocarbon source which is an ethanol-based source via catalytic decomposition, which then results in CNT growth which occurs at the metal substrate interface. The nature of the mechanism is still under research, but CCVD is still the predominant way to large-scale synthesis of CNTs.

Biomedical Applications

The ongoing investigation into carbon nanotube (CNT) applications in the biomedical field is still in its early stages but it has been well publicized, that CNTs hold considerable potential (Anzar, 2020). CNTs are usually said to be biocompatible because thus far, carbon represents a substantial portion of the body. A lot of biomedical applications require CNTs in the solution phase; however, the dispersion of CNT was historically difficult. A lot of times functionalization of single-walled carbon-nanotubes (SWNTs) is needed to achieve a higher degree of versatility and select applications (Tulin, 2009).

Aqueous suspension and precipitation of CNTs and the initiation of molecular interactions between them and biological systems needs a chemical modification. Various linear and non covalent as well as covalent modification methods exist. The noncovalent approaches do not apply structural perturbations to CNTs whereas the covalent modifications do. CNTs may be functionalized with the help of noncovalent techniques to bind with surfactants, aromatic organic compounds, fluorophores, polymers, lipids, DNA, and proteins (Tulin, 2009). Sidewall modification Covalent functionalization in general uses sidewall modification, which inserts higher concentrations of covalently grafted functional groups with substantial structural perturbation. Sidewall modifications; the most commonly used techniques of sidewall modification are fluorination, chlorination, bromination, hydrogenation, nitration, radical addition, nucleophilic addition, or an electrophilic addition. The possible uses of CNTs in medicine are addressed below.

Carbon nanotubes have been found promising as new therapeutic agents because of the large surface-to-volume ratio that could increase drug loading and release. They are easily covalently functionalized with targeting moieties allowing active transport and longer circulation. The potential of CNTs to serve as vehicle reservoirs to deliver drugs through controlled release because of the great surface-to-volume ratio is another advantage which can be controlled by pH and temperature, or molecular recognition. CNTs, furthermore, proved well-suited to targeted imaging, both due to their natural fluorescing nature, as well as their ability to be surface-labeled with targeted reporters. Probes can be coupled to the CNTs through covalent side-wall chemical modifications, and the nucleic acid aptamers which can achieve high specificity can be bound through noncovalent surface modification.

Diagnostic Tools

Biosensors

Diagnostic tests are the techniques that are used to measure the extent of pathological conditions. This can be achieved with carbon nanotubes (CNTs) that are used as artificial smart intelligence nanosensors and nanorobots. Such nano-scale devices shall be used *in-vivo* (Bhargava, 1999). Specifically, nanosensors sense the qualitative and quantitative changes in subtle physiological changes. In ophthalmic surgery, as an instance, they enable perfecting the procedures by reducing fluid change during the operations and controlling the vacuum-based fluid drainage (Sarwar *et al.*, 2010).

Biosensors are material-based nano-scale devices which are committed to the detection of diseases in various biological contexts. Nanobiosensors of CNT (carbon nanotubes) are being explored and employed more frequently to detect DNA series which are specific to cancer development and through this earlier diagnosis of tumorigenic indicators can be raised. Early diagnosis predicts lower metastatic potentials and therefore allows curative treatment by use of radiation therapy or chemotherapy which was directed. However, the discovery of the disease can be very delayed which results in a long disease process. Therefore, diagnostic methods are required to evidence sufficient sensitivity that would allow the occurrence of prognostic malignancy phenotypes of cells to illustrate that decisive treatment at the early stage of tumor development is possible. Two major types of CNT biosensor are in research development at the moment; these are the electric and the optical biosensors. The former because of its electronic architecture is commonly pegged with high sensitivity and accuracy compared to optical versions. Examples of subcategories of electric biosensors include Field Effect Transistors (FETs) and Amperometric sensors.

Biomedical Imaging

Biomedicine has grown simultaneously with fluorescence-using microscopically based technologies. With these imaging techniques, it is possible to characterize cells and tissues unlike before. At the center of this research are fluorophores which have a specific excitation, as well as emission spectra. Carbon nanotubes that are semiconducting, absorbing both ultraviolet and visible photons and emitting with sharp emissions in the Near Infrared (NIR) are of specific interest in this regard (Danne *et al.*, 2018). The combination of sensing and imaging makes possible (in principle) the chemical identification of biological systems with spatial resolution previously impossible. Previous limitations to the use of CNT-based fluorescent probes on in vivo imaging are due to toxicity, bioretention, and poor photoluminescence brightness. Recent statistics reveal that ultrashort CNT (< 100 nm) has a stronger excretion that reduces the possibility of bioretention (Hong *et al.*, 2015). Another nanomaterial, quantum dots, of rapidly increasing biomedical interest, has been conjugated to CNTs, and, alternately, functional groups attached to CNT surfaces have been used to synthesize quantum dots. Quantum dots and CNTs-based devices have been mainly used with electronic and photonic applications but very recent work is on their application as an intracellular fluorescence probe (Bottini *et al.*, 2006).

Nanotweezers

Probes refer to those used in analytical biology which seek to extract information on areas and cavities that cannot be analyzed in biological samples due to remoteness or uncertainties (Stevens *et al.*, 2000). A special sub-group is in the nanotweezer, which is a form of probe based on electrostatic force between two nanotubes on the tip. The concept of nanotweezer based on the balancing of the elastic restoring force of tapered glass micropipette and the electrostatic force arising between gold electrodes deposited onto the surface of the micropipette. To produce the moving components of the nanotweezer, commercially available instruments employ electrically controlled carbon nanotube bundles (usually of multi-walled nanotubes or MWNTs) connected to these electrodes (Tulin, 2009).

The latest nanotweezers technology is mRNA-activated multifunctional DNAzyme nanotweezers, applied to intracellular mRNA sensing and gene therapy (He *et al.*, 2021). Moreover, after a nanotweezer grasps an object at the nanoscale, then its electrical properties can be queried. New researches confirm that it is also possible to use nanotweezers as electromechanical sensors to detect a pressure or viscosity change in a medium by the resulting change in resonance frequency (Baughman *et al.*, 2002). The most recent work has been associated with growing the single-walled carbon nanotubes (SWNTs) directly onto the electrodes so that the membrane-based nanotweezers can pick up individual macromolecules.

Actuators

Actuators are equipment with the most basic objective of putting something to motion. They achieve this by transforming electrical energy to mechanical energy. After the completion of such conversion, the actuator uses the mechanical energy therefore gained to do good work. The major technical requirements of an actuator are that it should be low in weight, its maintenance voltage should be low, it should have a large displacement, high force, quick response time and possess a long cycle-life (Vohre *et al.*, 2004). Carbon nanotubes (CNTs) have however been recently discovered as a promising material in the process of manufacturing actuators. They are commonly utilized in biomedical engineering and find their serving purpose in the construction of artificial limbs, artificial ciliary muscles of the eye, irises, optical display units and pulsating hearts (Vohrer *et al.*, 2004). The high physio-chemical parameters of the nanotubes through effectiveness to resist high stress-strain loads and high electromechanical parameters make nanotubes a promising candidate to numerous biomedical surgical devices. Both the single-wall and the multi-wall nano tubes have been useful to various such devices (Gao *et al.*, 2000). Multi-walled ones in particular have that advantage due to their large surface area to volume ratio and good electrical conductivity, which would make them prime candidates of electromechanical application. An experimental setup was developed by Vohrer *at al.* (2004) to measure the actuation forces and speed, which during some test measures recorded the fastest actuation time of around 3 seconds.

Artificial Implants

Due to their unique chemical properties, which can potentially support tissue engineering and repair, nanomaterials have a stunning potential in the spheres of regenerative medicine. Carbon nanotubes (CNTs), whether of single-wall (SWNTs) or multi-wall (MWNTs) character, are a more effective use of a biocompatible type of implantable device which lessens the host-rejection in a much greater way at the time of their application within the joint prosthesis or other biomaterials. Additionally, CNTs have a high tensile strength therefore they can be applied as bone alternatives in synthetics in the event that they are impregnated with calcium and thereafter positioned into the pattern of the natural bone (Bian *et al.*, 2003). Nanoscale biosensors have also been developed to come in forms of implants to measure the heart activities and synchronize the heartbeat together with the implantable defibrillator. Future research of CNT being used in retinal diseases created by photoreceptor loss is worthy of exploration; bypass of the damaged photoreceptors so that the remaining ones activate instead and stimulate them directly are some of the possible solutions that can be pursued. Similar studies conducted on cochlear implants built on the basis of CNT research are likely to address the issue of auditory rehabilitation in persons with hearing impairment (Tulin, 2009).

Surgical Aids

In addition to being used in the diagnostic processes, nanotubes are also getting use in the surgical field. In the earlier surgical methods, the instruments being used were made of large macro size and were bulky to use by the doctors and therefore made the environment of the surgical field to be a mess. These macro level devices encouraged the occurrence of large wounds, severe postoperative pain, severe scarring and prolonged operating time and these factors normally contributed to fatigue in clinicians and subsequently increased risk of surgical accidents much more. Moreover, these instruments were macro-sized and were not very applicable in complex procedures of the eye, ear, and the nasal cavity. In order to overcome these shortfalls, nanosized artificially intelligent devices have been of great importance to develop (Sarwar, 2010). The nanotubes are also easy to process into nanoscopic surgical instruments making the surgery easier as well as sophisticated. Such nanoscaled devices as forceps, scalpels, and grippers include systems with sensors that guide the clinician to the area he or she wants to cut (Cavalcanti, *et al.*, 2007). During nanorobotic surgery, doctors manipulate the joystick controls that are used to control robotic arms fitted with the smaller surgical tools that are transmitted to the body through the portals. The other robotic arm is loaded with a small camera which provides a broad view of the operative site. These systems minimize fatigue of surgeons, limit patient pain and promote precision and safety. Further, nanorobotics also supplements single cell operations through endoscopic procedures in in vivo environment. Recent use of nanorobotics has developed in gallbladder, cardiac, prostate, vascular bypass, colorectal, esophageal and gynecological surgery. Knowledge in nanotechnology involves today the assemblage of strict architectural elements, operation mechanisms, and molecular-sized motor that may manipulate and move the nanoscale tools. The development of multi-wall carbon nanotubes (CNT)-based nanotweezers has proved that it is possible to structurally control and modify intracellular components. The friction constraints during manipulation pondered in the field of medical nanorobotics have been overcome by the discovery that multi-wall concentric arrangement of CNTs can be used to attain extremely low-friction nanobearing qualities (Cummings and Zettle, 2000).

Biopharmaceutics

Drug Delivery

Over the past few years, carbon nanotubes (CNTs) have drawn a significant academic attention by virtue of their ability to transport drug molecules to a designated biological location in a regulated way (Shiba *et al*., 2006). They have also been utilized in delivery of genetic material like DNA, genes and antibodies, targeted, controlled release of pharmacological material. The hollow inside of a CNT can be filled with the drug payload or drug can be attached onto its walls. Experimental research on CNT biodistribution reported that nanotubes functionalized with drug molecules find it easy to go through cell membranes and also have a tendency of going inside the nucleus, thus allowing site-specific delivery of drugs at the cellular and nuclear levels (Penman, 2003). The dimensional aspect became an essential parameter defining the CNT fate in vivo; lowest CNT delivery was possible under conditions when their size was avoided being on the macro or mesoscopic levels (Gao *et al*., 2015).

Blood-brain barrier (BBB) is a key hindrance to cross of exogenous therapeutic agents to the brain thus preserving the internal environment of the brain. The central neural system is actively involved in pathological conditions which are notoriously non-responsive to conventional pharmacotherapies due to the BBB and other enzymatic following pathological impedance to the neuropharmaceuticals and nutrients as well as the mineral ions. The existing drug-delivery systems that deliver the agents into systemic circulation are not effective to deliver the therapeutic molecules to the brain, and the lack of an effective brain-targeting system transports the therapeutic molecules to the brain is critical (Rautioa and Chikhale, 2004; Pardridge, 2005). As it can be seen in the current review, the existing state of brain-focused drug delivery systems needs reconsideration. Carbon nanotubes (CNTs) have gained significant attention of the academic community due to their ability to transport drugs across the bloodbrain barrier. Nevertheless, an optimal regimen needs to be defined: the release of the drug should be controlled because fast delivery may trigger the incomplete absorption of the drug, GI disruptions, and other side effects. Additionally, the carrier material needs to ensure that the drug degradation is avoided on during the journey through the body. Drugs are expected to be incorporated within encapsulation during transportation thus maintaining both biological and chemical activity (Kong *et al*., 2003). To this end the compatibility of drugs with their carriers is therefore crucial and the vehicle of delivery should disintegrate or be excreted upon cessation of therapy. According to research studies held at the University of California, there is a vast decrease in the amount of breast cancer when SWCNT is loaded with curcumin (Science News, 2005).

Blue-Brain Technology

The current question is to design a human brain that works as a supercomputer allowing a brain of anyone deceased to be uploaded to a computational substrate. The new approach that is the subject of investigation with the help of CNTs could give a chance to sustain the cognitive and the affective abilities of a person even after biological death. The biggest question is: is it possible that an artificial neural network is the re-creation of human experience that is how to perceive the world, how to interpret it, how to act in it without the fundamental difference to biological cognition? Its proposal is yes. Physical process of importing human brain, known as a blue brain, is based on an army of nanorobots, nanobots, that move through the circulatory system to the cortex and backbone in bio-like format. By sampling neuronal populations, neural activity configurations and the structural interconnections these agents record the full readout of organization of the central nervous system. After these data becomes digitized, it may be loaded into a computational architecture, and at that point the stored representation comes to continue simulating as a functional model of the original brain. In such a way, one of the groups of functions of blue brain is retaining and reinstating the cognitive and affective contents of the brain code that was written in the neural net of the deceased person (Ramesh, 2020).

Such a methodology also assists in quick diagnosis of Parkinson disease. The in-vivo neural activity dataset enables developing patient-specific treatment approaches and reading of clinical risk profile at the same time. Furthermore, the recordings that are available due to the long-term implantation allow gaining considerable knowledge about the adaptation of the nervous system to the influences of the environment and the treatment with medications. Moreover, a generalization of the model to in-silico systems, e.g. blue brain drug-discovery pipeline, has also allowed investigators to employ the platform to query very large in-silico neurobiological datasets using more sophisticated ontology-based queries. Blue brain is therefore a pivotal and physiological point of reference to whole-brain simulation, using the software package NEURON which was initially developed by Michael Hines and John Moore.

The project under consideration could consist of the following specifications: Nanobots as the interface connecting the supercomputer with the natural brain, super fast processor in which the ability to emulates billions of neurons occurs, storage memory with a capacity of up to 20 Terabytes and software that is designed to translate electrical impulse emanating in the brain into input data of the super computer. The drawbacks related to this proposed architecture include the following: breaking access to neural schema by hacking can be used against the same person, increased reliance on computational technologies can lead to this, and the worst risk is that machines can become hostile to their human counterparts (Hepzebah *et al.*, 2020).

Problems, Challenges and Barriers Associated with CNTs

Prior to putting using CNTs in the environments there are certain obstacles that have to be overcome. One drawback is as well the fact that they do not dissolve in aqueous solvents although scientist have circumvented this issue by treating the surface of CNTs i.e., brushing them with various hydrophilic molecules to enhance their water solubility and biocompatibility (Wu *et al.*, 2004).

The other CNTs impediment is the biodistribution and pharmacokinetics of nanoparticles which is influenced by a lot of physiochemical properties.

TOXICITY of CNTs is also another significant barrier. CARBON NANOTUBES seem to have no considerable toxic effect in cells, as they have been seen to grow on them. Conversely, it has been observed that carbon nanotubes disrupt the process of cell division in bacteria and terminate it as soon as they are consumed (Bekyarova *et al.*, 2005). This may be understood in a variety of ways:

1. as a poisonous effect.
2. as a method of chemotherapy in inhibiting division of cancer cells, and;
3. as drug delivery targeting.

The size of nanotubes may influence the toxicity of CNTs. The properties of the particles which are less than 100 nm are harmful since they have increased potential toxicities to the lung, and evade the normal phagocytic defenses (Ali *et al.*, 2014). CNTs would also assist in the transport of toxins and more so to the deeper soils since they have a larger surface area and become adsorbed with the pollutants and also transported in the soil to mean that the pollutants were adsorbed more and deeper than usual and likely to form possibly newer toxic compounds as a result of strong catalytic activities.

Regulatory Aspects of CNTs

The debate of regulatory measures has heightened following a significant raise in the public and scientific interest in nanotechnology over the past few years. The question that arises is whether nanotechnologies are to be regulated at all, and by whom and in what ways, predominately concerning the manufacturing procedure, and the bio application of nanotechnologies in animal and human use. The example of carbon nanotubes (CNTs) demonstrates this issue and the need of carrying out toxicity testing of high quality, thorough environmental risk assessment, as well as managing occupational exposure. Dermal contact with CNTs, inhalation, and ingestion are the key pathways through which the former enters the body. Inside, their bioavailability is displayed as excellent, and they can cross bloodstream, gastrointestinal tract, surface tissues, and the blood-brain barrier seemingly without any problem. The extent of potential health impact is determined by whether properties of nanomaterials are toxic or not. CNTs may remain in the respiratory tract and pulmonary circulation and, since CNTs can yet be functionally modified, may raise the probability that the inhaled ultra fine forms dodge the macrophages that would otherwise clear the fine particles. Ultrafine CNTs are therefore easily displaced out of alveolar areas to the bloodstream which can spread to important organs.

Conclusion

The concept of carbon nanotubes (CNTs) is one of the most central ones in terms of modern debates concerning regenerative medicine. Their aptitude to biomedical use is anchored on their complementary nature of their exclusive chemical and physical properties, which endows them with the possibility of solving several challenges in drug delivery and also in diagnostic technologies. Such is the case that CNTs have been developed as a multifunctional nanocarrier system and have been studied especially energetically to be applicable in therapeutic and diagnostic applications. The popularity of these studies is explained by the specifics of composites made of CNTs that allow building a diverse wide structure, high mechanical strength, and enable conductive electronic performance at the same time. Due to these properties, CNTs find usage in sensor arrays, probes, actuators, composite scaffolds, nanoelectronics devices and, more recently, on a personalized drug-delivery platform. These nanomaterials have elucidated a lot of interest among the industrial researchers and academia in a relatively short period of time.

Within the past 20 years, a significant amount of work was done toward the characterization and development of biomedical uses of CNTs. Functionalizing tactics have been optimized, paving the way to attaching a range of various natural moieties, and hence enlarging the set of possible biological interactions. CNT based probes have now created several new possibilities of application in the field of imaging as well as of targeting, which are specifically suitable to cancer therapy and infection treatment activity. It has been shown that CNT drug-carrier constructs have been shown to have promises of great therapeutic efficacy in oncology showing low systemic toxicity profile, and low drug doses combined. These results taken together highlight the potential that CNTs have toward regenerative medicine and the sign of their ability to become a crucial aspect of biomedical arsenals in the future.

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