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Carbon Nanotubes in Biomedical Applications: Factors, Mechanisms, and Remedies of Toxicity

Miniperspective

Reem Alshehri[†], Asad Muhammad Ilyas[‡], Anwarul Hasan^{*§||}, Adnan Arnaout[§], Farid Ahmed[‡], and Adnan Memic^{*†}[†] Center of Nanotechnology, King Abdulaziz University, Jeddah, 21589, Saudi Arabia[‡] Center of Excellence in Genomic Medical Research, King Abdulaziz University, Jeddah, 21589, Saudi Arabia[§] Department of Mechanical and Industrial Engineering, College of Engineering, Qatar University, Doha 2713, Qatar^{||} Biomedical Engineering and Department of Mechanical Engineering, Faculty of Engineering and Architecture, American University of Beirut, Beirut 1107 2020, Lebanon^{*} Biomaterials Innovation Research Center, Division of Biomedical Engineering, Department of Medicine, Brigham and Women's Hospital, Harvard Medical School, Boston Massachusetts 02115, United States

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*A.H.: e-mail, ahasan@qu.edu.qa and mh211@aub.edu.lb; phone, +97470569169., *A.M.: e-mail, amemic@kau.edu.sa; phone, +966564975404.

Biography

Reem Alshehri received her B.Sc. and M.Sc. in Biochemistry from King Abdulaziz University, Jeddah, Saudi Arabia. Her research area concentrated on the mechanisms of mercuric compound toxicity and their role in initiating of oxidative stress, autoimmunity, and response of autistics to organic forms of mercury. Her research interests include molecular mechanisms contributing to autism and neuroscience and using nanotechnology tools in the treatment and diagnosis of neurodegenerative diseases.

Biography

Asad Muhammad Ilyas graduated with a B.Sc. in Biology. He received his Master's degree from University of Skovde, Sweden, with a major in Molecular Biology in 2010. He completed his Ph.D. in Biochemistry with a major in Molecular Biology from King Abdulaziz University in 2016. His research focuses on targeting multiple signaling pathways for the treatment of acute myeloid leukemia, including interventions using nanotechnology. In addition, his research focuses on studying the mechanism of cancer related genes in the development of leukemic hematopoiesis.

Biography

Anwarul Hasan, Ph.D., P.Eng., is an Assistant Professor of Biomedical Engineering and Department of Mechanical Engineering at the American University of Beirut, Lebanon, and the Department of Mechanical and Industrial Engineering at Qatar University, Qatar. He is also a visiting Assistant Professor at the Harvard Medical School (HMS) in Cambridge, MA, U.S. Earlier, Dr. Hasan worked in industry during 2010–2011 and was a National Science and Engineering Research Council of Canada (NSERC) Fellow at Harvard and Massachusetts Institute of Technology during 2012–2013. Dr. Hasan obtained his Ph.D. from University of Alberta, Canada, in 2010. His current research interests are in the areas of biomaterials, biomechanics, and tissue engineering, particularly for cardiovascular, bone, and neural applications.

Biography

Adnan Arnaout is a fourth year mechanical engineering student at the American University of Beirut, minoring in biomedical engineering, with special interest in tissue engineering. He is an undergraduate researcher at the Nano Micro-Technologies and Tissue Engineering Lab at the American University of Beirut. His research focuses on developing hydrogels for tissue engineering, as well as microfluidics.

Biography

Farid Ahmed completed his Ph.D. in Human Biology from the Ludwig Maximilians University, Munich, Germany, in 2006. He performed his postdoctoral studies at the Clinical Co-Operative Group-Leukemia in Munich. Dr. Ahmed's current research interests are studying the molecular regulation of normal and malignant hematopoiesis and HSC self-renewal with the hope to identify underlying processes that lead to leukemic transformation and progression. Projects in Dr. Ahmed's group focus on identification and characterization of candidate leukemic stem cell (LSC) in hematopoietic malignancies and therapeutic targeting of the leukemic cells that drive human leukemia. Dr. Ahmed is currently a

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member of several scientific societies such as International Society for Stem Cell Research (ISSCR), European Hematology Association (EHA), and ISEH—Society for Hematology and Stem Cells.

Biography

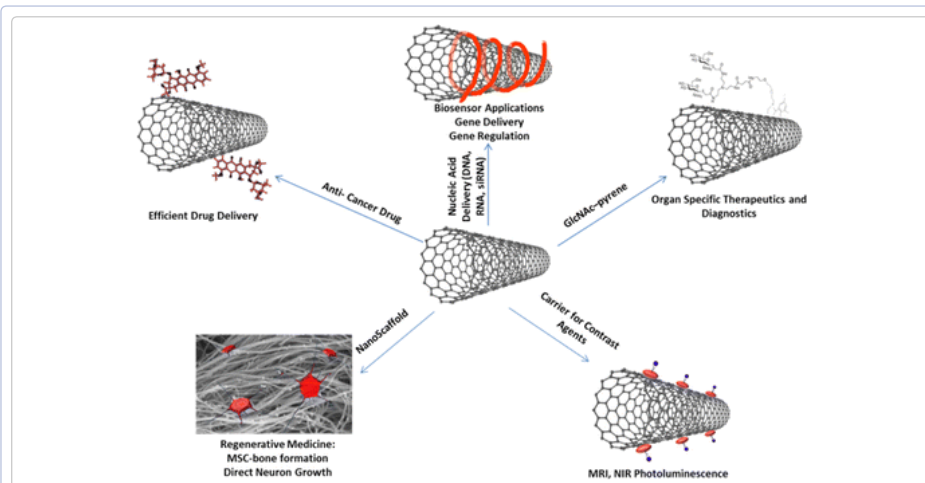
Adnan Memic graduated summa cum laude with a B.Sc. in Chemistry. He received his Ph.D. in Chemistry/Biochemistry from Wayne State University, Detroit, MI, U.S., with Mark Spaller. He was a postdoctoral fellow in Chicago with Brian Kay at the University of Illinois. He was previously a Visiting Assistant Professor of Toxicology and Pharmacology at Dartmouth's Geisel Medical School. He joined King Abdulaziz University in 2010, was promoted to Associate Professor of Nanotechnology, and is concurrently a part-time Lecturer on Medicine at Harvard Medical School. His research focuses on bioactive molecule discovery and development including generation of biomaterials, carbon nanomaterials, chemical and peptide analog libraries, protein and antibody engineering toward solving challenges in targeted drug delivery, biosensing, and tissue engineering and regenerative medicine applications.

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Abstract



Carbon nanotubes (CNTs) represent one of the most studied allotropes of carbon. The unique physicochemical properties of CNTs make them among prime candidates for numerous applications in biomedical fields including drug delivery, gene therapy, biosensors, and tissue engineering applications. However, toxicity of CNTs has been a major concern for their use in biomedical applications. In this review, we present an overview of carbon nanotubes in biomedical applications; we particularly focus on various factors and mechanisms affecting their toxicity. We have discussed various parameters including the size, length, agglomeration, and impurities of CNTs that may cause oxidative stress, which is often the main mechanism of CNTs' toxicity. Other toxic pathways are also examined, and possible ways to overcome these challenges have been discussed.

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