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Nanomaterials for the Repair of Spinal Cord Injury

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Spinal cord injury is a most devastating desease, as it causes a permanent loss of motor functions, causing enormous personal, social and economic problems. Neural regeneration has been shown to be a natural process; however, the regeneration mechanisms of the central nervous system are generally ineffective in restoring appropriate function. Therefore, there is tremendous social and medical pressure and research interest to discover new therapeutic strategies for effective repair of spinal cord injury. Repairing spinal cord injuries is far from simple, but new interdisciplinary research approaches through cutting-edge technologies and revolutionary concepts are raising hopes in promoting effective self-repair strategies. Cell- and biomolecule-based delivery strategies and therapeutic strategies based on novel tissue regeneration scaffolds have been developed in this direction. More recently, with a trend towards a combinatorial approach, regenerative/neural engineering therapies, prosthetics, neural engineering, rehabilitation engineering, bio-inspired robotics have been combined to develop advanced intelligent systems that promote spinal plasticity, regeneration and repair. Nanomaterials are increasingly being used in this field, especially due to their size, which allows a particularly efficient control of their physical and chemical properties. In fact, connecting nanostructured materials to biological compartments is a crucial step in prosthetic applications, where the interfacing surfaces should provide minimal undesired perturbation to the target tissue. Ultimately, the (nano)material of choice has to be biocompatible and promote cellular growth and adhesion with minimal cytotoxicity or dis-regulation of, for example, cellular activity and proliferation. In this context, carbon nanomaterials, including nanotubes and graphene, are particularly well suited for the design and construction of functional interfaces. This is mainly due to the extraordinary properties of these novel materials, which combine mechanical strength, thermal and electrical conductivity. Our group has been involved in the organic functionalization of various types of nanocarbons, including carbon nanotubes, fullerenes and, more recently, graphene. The organic functionalization offers the great advantage of producing soluble and easy-to-handle materials. As a consequence, since biocompatibility is expected to improve upon functionalization, many modified carbon nanomaterials may be useful in the field of nanomedicine.

In particular, we have recently shown that carbon nanotubes and graphene can act as active substrates for neuronal growth, a field that has given so far very exciting results. Nanotubes and graphene are compatible with neurons, but, especially, they play a very interesting role in interneuronal communication. Improved synaptic communication is just one example. During this talk, we will discuss about the most recent attempts to regenerate the electrical connection between the fractured sides of the spinal cord, with particular emphasis on the latest and most exciting results obtained in our laboratories in this fast developing field.

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