Nanomaterials and neuronal hybrid systems: first steps in Nanoneuroscience

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Nanoneuroscience is a new discipline, characterized by strong convergence of nanotechnology, chemistry, engineering and neurobiology. It focuses both at clinical applications (i.e. multifunctional / hybrid devices for CNS repair and/or interfacing) as well as at basic research problems (see Giugliano et al., 2009; Silva, 2006; Sucapane et al., 2008, for review).

During the presentation, emphasis will be given to the biophysical interactions occurring between networks of neurons and Carbon Nanotubes (CNTs). These nanoparticles are extremely popular in today's top basic and applied nanotechnological research. Their electronic properties are the most relevant for the electrophysiological interactions with the nervous systems, and are known to be direct consequence on the geometrical properties of the underlying hexagonal lattice structure. Carbon nanotubes further display unique mechanical and physico-chemical properties, and their use as new material for future industrial applications, ranging from nanoelectronics, CNT-based transistors, CNT-based biosensors, to the aerospace industry, is covered by media almost daily.

With specific regards to cell neurobiology, CNTs can be functionalized to display a variety of surface charges, as well as to bind specific (neuro)active compounds (both with physiosorption and covalent bonding). Because of the ease of surface functionalization, at the beginning of the decade, several researchers showed that CNTs - meshworks were excellent substrates for the growth and the development of ex vivo neurons and networks, possibly constituting ideal materials for designing nerve-tissue scaffolding and prosthetics (Mattson et al., 2000; Hu et al., 2004; Liopo et al., 2006; Galvan-Garcia et al., 2007).

However, the functional (electrophysiological) effects of growing neuronal networks on CNT substrates were largely neglected until recently. Simple observations of a very general form of spontaneous patterned activity (i.e. irregular 'bursting'), emerging in living networks of cultured neurons, dissociated from almost all CNS regions, gave rise to an unexpected discovery, summarized as a "boosting effect of the electrical activity of neuronal circuits" (Lovat et al., 2005). Far from being understood and dissected in all its cellular and molecular mechanisms, we are strongly convinced that such effects might be exploited in future engineered CNS implants, or in bridging devices, to re-establish or boost electrical communication between damaged tissues, or to replace nerve pathways severed by trauma or diseases.

Further reading (e-reprints at http://www.giugliano.info/pro/pubs.php)
Giugliano et al., (2009) Drug Discovery Today: Disease Models
doi:10.1016/j.ddmod.2008.07.004
Cellot et al. (2008) Nature Nanotech.
Lovat et al. (2005) Nanolett 5(6):1107-10.
Mazzatenta et al. (2007) J Neurosci 27(26):6931-6.

Sucapane A et al. (2008) J Nanoneurosci. 1:1-7; and references therein.
Silva GB (2006) Nat. Neurosci Rev 7:65-74.

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