Theoretical design and surface patterning of nanoparticles and biopolymers for translocation through phospholipid bilayers

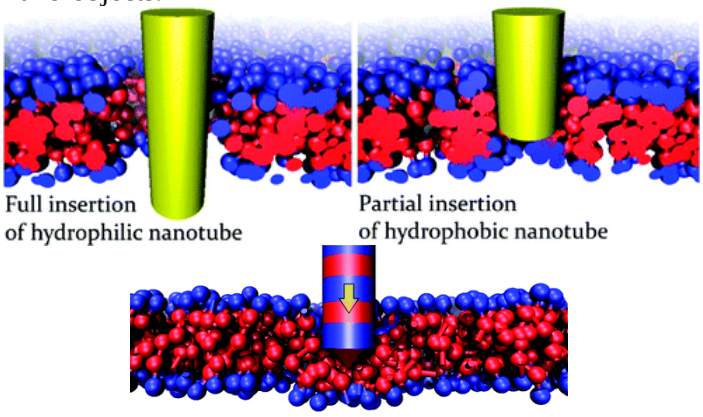
Sergey Pogodin[1], Nigel Slater[2] and Vladimir Baulin[1,3]

[1] *Departament d'Enginyeria Química, Universitat Rovira i Virgili, av. Països Catalans, 26, 43007 Tarragona (Spain)*
[2] *Department of Chemical Engineering and Biotechnology, University of Cambridge, Pembroke Street, Cambridge CB2 3RA, (UK)*
[3]*Institució Catalana de Recerca i Estudis Avançats, Passeig Lluis Companys 23, 08010 Barcelona (Spain) – vladimir.baulin@urv.cat*

Abstract

Understanding the mechanism of transduction of biomaterials through cell membranes is a challenging undertaking from many perspectives. Apart from fundamental interest, details of the mechanism may answer questions about the cytotoxicity of nanoparticles and biopolymers, and their potential use as delivery vehicles or to probe bilayer properties. However, despite considerable effort devoted to this question, a consensus on the mechanism has not yet been reached and direct evidence of spontaneous translocation of many biomaterials through the cell membranes is still lacking.

To address this question, a coarse grained model of the phospholipid molecule was adopted, which had been previously shown to adequately describe the key thermodynamic properties of a phospholipid bilayer in a fluid phase[1]. We have studied first the translocation of a carbon nanotube with uniform surface properties through a phospholipid bilayer[2]. We have shown that hydrophilic and weakly hydrophobic nanotubes face a substantial energy barrier to penetration, whilst intermediate and strongly hydrophobic nanotubes penetrate little or become entrapped in a free energy well within the bilayer. This indicates that carbon nanotubes with uniform surface properties would have difficulties to pierce spontaneously the phospholipid bilayer. In a biological media spontaneous patterning may occur naturally upon self-assembly of biomolecules onto the surface of nanotubes. It results in periodically alternating bands of surface properties, ranging from relatively hydrophilic to hydrophobic, along the axis of the nanotube. In contrast to un-patterned nanotubes with uniform surface properties, certain patterned nanotubes have been identified that display a relatively low and approximately constant system free energy as the nanotube traverses through the bilayer[3]. These observations support the hypothesis that the spontaneous self-assembly of biomolecules on the surface of nanotubes may facilitate transduction of biomaterials through cell membranes. Similar behaviour is observed for spherical nano-objects.



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[2] Sergey Pogodin and Vladimir A. Baulin, "*Can a carbon nanotube pierce through a phospholipid bilayer?*", ACS Nano, **4**, 5293-5300 (2010)
[3] Sergey Pogodin, Nigel K. H. Slater and Vladimir A. Baulin, "*Surface patterning of carbon nanotubes can enhance their penetration through a phospholipid bilayer*", ACS Nano, **5**(2), 1141–1146 (2011)