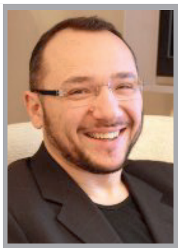
Nanorobots for medicine: how close are we?

"...film and scientific exploration at the nanoscale have been lending each other imagery and targets to achieve."



Kostas Kostarelos
Author for correspondence:
Nanomedicine Lab, The School of Pharmacy University of London, 29-39 Brunswick Square, London WC1N 1AX, UK
Tel.: +44 207 753 5861
kostas.kostarelos@pharmacy.ac.uk

Since the pioneering vision of Feynman in his now famous lecture 'There's Plenty of Room at the Bottom' first delivered at an American Physical Society meeting at Caltech in December 1959 [1], film and scientific exploration at the nanoscale have been lending each other imagery and targets to achieve. It took only 5 years from Feynman's lecture for a fellow resident of Los Angeles, Harry Kleiner, to complete the script for the film 'The Fantastic Voyage' that was released in 1965 to popularize 'miniaturization for medicine' like no scientist could ever do. The inspirational power of miniaturizing matter to navigate throughout the human body and reach the brain to remove aneurysm-causing blood clots depicted in the film, even transcended into the art world thanks to Salvador Dalí and his painting 'Le Voyage Fantastique' portraying the voyage in to the human subconscious, a result of the painter's direct involvement in the production of the film (Figure 1).

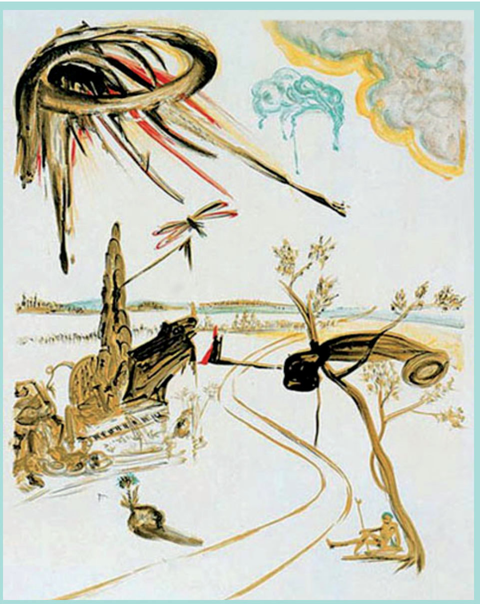


Figure 1. 'Le Voyage Fantastique'.
© Salvador Dali, Fundació Gala-Salvador Dali, DACS, London 2010.

Today, 45 years after this first cinematography-originated use of nanotechnology for medicine, numerous scientists, thinkers, film makers and authors have been describing how this powerful technology can assist us to explore the nanoscale of the human body. However, one question still persists. Where do fantasy, imagination and science fiction stop and where does 'real' science and medicine start? The answer is that even though dramatic developments in technology and engineering at the nanoscale have occurred in the last decade, we are still at a state of infancy regarding the capability to design, manufacture, control and navigate nanorobots (nanomachines, nanobots, nanoids, nanites and nanonites or however else described) and purposefully use them for diagnosis or therapy. Some of the most critical challenges are discussed below.

Powering the nanodevice

Devices at the nanoscale, thousands of times smaller than the period at the end of this sentence, experience water as a viscous, honey-like matter (flowing blood or other bodily fluids are even thicker than water due to the large concentration of proteins and salts) and will therefore require considerable energy consumption to be able to propel and navigate towards a target.

Communication & triggered action

Diagnostic or therapeutic activity by the nanorobot will need to be timed at specific sites in the body. This will require sophisticated and well-controlled initiation of activity (preferably wirelessly), which is not currently feasible.

Safety

Irrespective of capability for navigation and activity, any nanodevice designed for administration in patients will need to be toxicologically inert, degradable or expelled from the body.

There is active research taking place in various laboratories around the world on the manufacturing of prototype components for nanorobots that consist of various materials such as diamond, fullerene carbon, silica and DNA.

"...the question of whether nanorobots revolutionising medical practice is a conceptual marvel or a delusional heresy will remain unanswered for years to come."

In the past year, two examples of artificially engineered miniaturized propelling systems termed 'swimmers' were manufactured and described in the literature (Figures 2 & 3) [2,3]. Both examples are capable of directional navigation in aqueous environments by externally applied magnetic fields and have the capacity to be mass manufactured, however no biological activity has yet been demonstrated.

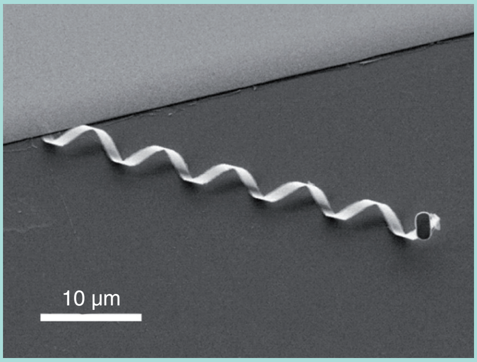


Figure 2. Artificial bacterial flagella. Field emmission scanning electron microscopy image of an untethered ABF made of InGaAs/GaAs/Cr helical tail.
Reproduced with permission from [2].

One thing is for sure, technological progress in the design and engineering of nanorobots is certainly going to advance in the immediate future. However, the question of whether nanorobots revolutionizing medical practice is a conceptual marvel or a delusional heresy will remain unanswered for years to come. In the meantime, we will be surely continue to be thrilled by the power of nanotechnology as depicted by Hollywood studios and in popular science fiction.

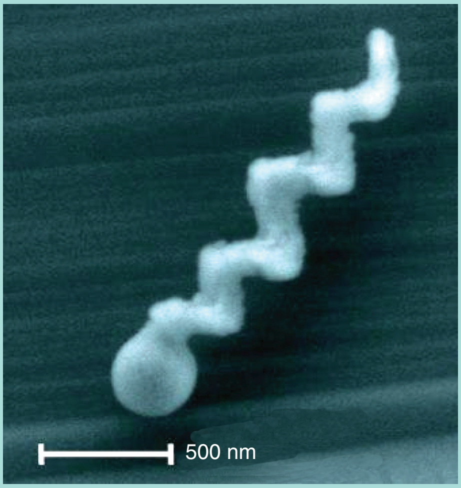


Figure 3. Artificial magnetic nanostructured propeller. Scanning electron microscopy image of an individual glass screw with nanostructured helicity .
Reproduced with permission from [3].

Financial & competing interests disclosure

The author has no relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript. This includes employment, consultancies, honoraria, stock ownership or options, expert testimony, grants or patents received or pending, or royalties.

No writing assistance was utilized in the production of this manuscript.

Bibliography

1 *Annual Meeting of the American Physical Society*. California Institute of Technology (Caltech), 29 December (1959).

2 Zhang L, Abbott JJ, Dong L, Kratochvil BE, Bell D, Nelson BJ: Artificial bacterial flagella: fabrication and magnetic control. *Appl. Physics Lett.* 94 (064107), 1–3 (2009).

3 Ghosh A, Fischer P: Controlled propulsion of artificial magnetic nanostructured propellers. *Nano Lett.* 9(6), 2243–2245 (2009).