



## How we got here, where we are going and being a cog in something turning

*“...nanomedicine is one of the most important subjects at the very cutting edge of modern science and ... Nanomedicine is the voice of this efflorescent discipline.”*

I am delighted that *Nanomedicine* will be going to eight issues in 2009, only 3 years after the journal's inauguration. This means that the scientific subdiscipline of nanomedicine is growing and that our namesake journal is proving to be the primary voice of this new field. How did we get here? Let me begin with a little of my personal journey. This will lead us to some key emergent scientific and technological themes, none mine, that have shaped nascent nanomedicine. These themes are expressed in the pages of *Nanomedicine* today, and expressed in ways that would have seemed like science fiction 10 years ago.

When I moved to the University of Florida 10 years ago, I had this idea that the field of 'bio/nano' was going to be important. This idea certainly did not originate with me. Earlier research and development efforts on particle-based drug-delivery systems piqued my interest in things bio/nano. And the research that led to the 2003 Nobel Prize to Agre and MacKinnon led me to a Eureka moment – biological ion channels can be viewed as nanomachines that use electromechanical motion to accomplish their critical biological functions. I was so excited about this revelation that my laboratory began research on the development of artificial nanotube-based ion channels. Finally, one of the first lectures I attended after moving to Florida was by future Nobel laureate Roger Tsien on combining mutants of green fluorescent protein with the  $\text{Ca}^{2+}$ -binding protein calmodulin to make sensors for real-time measurement of free  $\text{Ca}^{2+}$  concentrations in living cells. Again, I saw a bio/nano machine, this time coupling the  $\text{Ca}^{2+}$ -induced change in the shape of calmodulin to a modulation of fluorescence intensity. And, at heart, this machine was a sensor, a subject of great interest to me since my graduate school days.

The journey has been fun for me, and the bio/nano field has since evolved into one of the cornerstones of modern nanotechnology. But a natural, twofold, consequence of that evolution

has been: to increase the importance of applying developments in bio/nano technology to living systems – Tsien's work is a beautiful example; and to apply the spectacular advances in bio/nanoparticle design and synthesis to the treatment of disease in humans, a natural extension of the earlier work on particle-based drug delivery. The field of nanomedicine came from this scientific evolutionary process, and if we turn to the recent pages of *Nanomedicine*, we see these themes reflected in abundance there.

For example, we had two special issues on nanoparticles for disease diagnosis and treatment, one on nanoparticles to combat cancer edited by Sang Bok Lee, and the other on nanomaterials for biomedical diagnosis, edited by Y. Charles Cao. The key word today is 'multifunctional' – spherical and tubular nanoparticles with surface functionality that targets them to specific cells or across recalcitrant biological barriers, filled with genes, silencer RNA, chemotherapy agents and so on. Magnetic nanoparticles are of particular recent interest with applications as diverse as nanoparticle targeting, magnetic nanothermotherapy and MRI. Nanoparticle toxicity is also an emergent motif. There were essentially no reliable data here 5 years ago, but they are being published in *Nanomedicine* today. I offer my congratulations to those nanomedicine pioneers, including our editor Kostas Kostarelos, who moved so quickly to fill this void.

New concepts in biosensing are also a dominant theme for *Nanomedicine*. In general, a sensor has two key components: an analyte-recognition system that allows the device to selectively detect the desired analyte species; and a transduction system that turns that recognition process into a measurable electrical signal. When I completed my PhD in biosensors in 1980, the biggest challenge was the recognition system. We learn from recent papers in *Nanomedicine* that a powerful paradigm for building this system entails attaching biochemical recognition agents (e.g., antibodies, receptor proteins



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and DNA) to nanostructures. Assays based on both biofunctionalized nanoparticles and nanotubes are being developed. Signal-transduction schemes that have made use of such functionalized nanostructures include new surface-plasmon resonance systems, quantum dot fluorimetry, fluorescence resonance energy transfer and single-molecule counting in nanopores.

I introduced the subject of nanomachines by referring to what I learned from some very smart Noble laureates. But there is another laureate that should be recognized here, Richard Feynman, who as Huang and Juluri point out in their beautiful nanomachine review [1], originated this concept in 1959. My definition of genius is the person who can look at the same facts, events and information that others see, and yet synthesize a completely new and unique vision based on these data. Geniuses are also typically way ahead of their time. That too was Richard Feynman.

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In fact, there are two nice reviews of nanomachines in the recent pages of *Nanomedicine* [1,2]. The Huang and Juluri paper is very general and teaches us about the biological myosin and kinesin motors, the rotary ATP-synthase system and biomimetic molecular machines. It's a great read. In addition, Dynan *et al.* [2] introduce us to the nanomachines present in the cell nucleus that carry out DNA replication, messenger RNA synthesis and DNA repair. They then focus on a specific machine of this type that repairs breaks in dsDNA, and discuss how this machine might be turned to medical advantage to repair mutations that lead to cancer.

All of the examples I have discussed here reinforce my two main points – that nanomedicine is one of the most important subjects at the

very cutting edge of modern science and that *Nanomedicine* is the voice of this efflorescent discipline. Let me conclude, now, with some comments on the politics of scientific publishing. Some of my more ambitious colleagues point out to me that there are nano journals that currently have higher impact factors than *Nanomedicine*. Why shouldn't they publish their best work there? My response is three-fold. First, the only reason our impact factor is currently not higher is that we are young. No other journal of this type had a higher impact factor at a comparable stage of development. Second, I point out that I publish my best work in *Nanomedicine*, so clearly I am convinced of the importance of this journal. And, finally, I return to what I said at the beginning about the evolution of a new field. I want to be a part of that process. To quote the great Canadian songwriter Joni Mitchell, “I want to feel myself a cog in something turning.” Rightly or wrongly, my guess is that those who publish now in *Nanomedicine* will be viewed by history as pioneers of nanomedicine. I want to be in that roll call, how about you?

#### Financial & competing interests disclosure

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