Workshop on Bioimaging and Engineered Biosystems at Lehigh University
September 28-29, 2006

Breakout discussion session:

The Impact of Nano-Science/Engineering on Bioimaging and Biomedical Technology

Summary of the discussion

In recent years, two areas of exceptional growth have become obvious: these are "nano" and "information technology". Most researchers are now comfortable with defining what nano is, however, we need to understand better what impact the research in nano will have on other fields. To develop understanding of the challenges for nano in biologically related fields, there is a need for biologists to illuminate better pertinent problems for physicists, chemists, and engineers.

The issues related to nanoparticles figured prominently into discussion with at least half of the time devoted to various aspects of science and applications of nanoparticles. The following challenges have been identified as critical to further the impact of the nanoparticle technology on biological systems:

- Surface chemistry needs to be robust and a general "surface chemistry toolbox" needs to be developed, so that reproducible methods/protocols can be easily adopted by non-chemists working with nanoparticles;
- The current methods produce particles of inadequate level of heterogeneity (broadly defined, as having too wide of a distribution of sizes, defects, surface functional groups, coverage, etc.);
- The nanoparticles are often found prone to aggregation, which is undesirable;
- Mechanical stability of surface functionalization (stabilization) can be very poor, for example, a simple pressure driven filtering prior to application can result in stripping of some of the surface bound ligands/surfactants;
- There is clearly a need to develop approaches to achieve strong covalent bonding between metal and semiconductor nanoparticles and organic ligands;
- Use of multivalency to produce robust binding appears to be a viable approach for nanoparticles.
- The issue of toxicology of nanoparticles has being prominent in the media and on the minds of funding agencies, however, no systematic/quantitative studies have emerged or being published. There are no clear guidelines or data in the literature that one can turn to address the issue of toxicity of the nanoparticles.

Some of the above problems are even known to occur in commercial NP products. In discussion of the application of nanoparticles in biomedicine, several topics of current interest emerged:

- poorly documented biocompatibility (related to toxicity issue above);
- in case of drug delivery applications, the issues related to nanoparticle (delivery vehicle) and drug itself should be well-separated;
- design and applications of nanoparticles with multiple functionality;

- development of probes with triggerable response, e.g. delivery of the material (drug, nanoparticle) to a target location/tissue followed by stimulation of various nature (mechanical, optical, electrical, etc.) to achieve a desired effect at the targeted locus.

The last points has implications for a broad issue of implementing electrical (or other) stimulation of the cell at small scale whether to access cell signals, molecular sensing, detection, or influencing the cell behavior in a particular way.

One of the big problems researchers in basic sciences face when moving results of their nano-based research from the lab to clinic is difficulties they experience in the interaction with medical professionals (culturally, and due to sometimes radically different priorities/importance assigned to working on various aspects of disease treatment). In addition, one-time demonstrations in laboratories often are not relevant for clinical applications, because high throughput is important for medical settings.

Another important theme in discussion on challenges for nanoscience in biomedicine is the amplification of the receptor signal, i.e. the interaction of the probe with a single receptor in the cell always produces a signal corresponding to just that one receptor and means of detecting it are limited. The sensitivity of nanometer sized probes will be improved when some mechanisms for amplification are developed. It was noted by one of the participants that signal amplification or sensitivity afforded by new nanomaterials and nanodevices will have some major societal implications. For example, it was his believe that “in 20 years everyone will have their genome sequenced at birth – whether you want it or not.” Nanotechnology will have a big role in such applications.

One of the possible issues facing nanoscience in biology is the application of methodology used in engineering of nanometer scale materials, processes, and devices to biological systems. The tools of engineering biology (i.e. replicating/moving a particular cell function from the cell into engineered system) at nanometer scale do not exist today and it is important to keep in mind both the systems approach and educational aspect of this unexplored field. Possible contribution of nanosciences to engineering biology will include (i) real time readout of biologically related signals, (ii) multiscale approaches to modeling of nanosystems in biology, and (iii) contribution to efficient transfer of technology/knowledge from in vitro to in vivo studies.

The introduction of MEMS and NEMS to bioimaging and engineered biosystems is also expected to have a major impact in (i) non-traditional imaging, (ii) implantable devices, and (iii) research related to brain-computer interface. Nanoscience is expected to contribute to our ability to design new proteins, which can help reverse the Alzheimer's disease and similar conditions, as well as to contribute to work on nerve regeneration in general.