

2nd Annual National Academies Keck *Futures Initiative* Conference
*Designing Nanostructures at the Interface
between Biomedical and Physical Systems*
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An In Vivo Nanofactory: the Medicine of the Future
Focus Group Description

Background

Science fiction writers have conjured up bacterial colonies as future large scale factories of engineered nanomaterials or nanomachines, which could then be assembled or self-assemble into macroscale objects useful to society. The convergence of nanotechnology with biotechnology has the potential to enable engineered biological processes to catalyze, 'grow' and assemble complex engineered objects (Ref. 1). One step forward in this future vision is to use engineered biological (bio-mimetic) processes to create a desired step in such an assembly process, such as to create a nano chemical factory to synthesize 3 amino acids in a row, to synthesize a drug, or to perform a function such as closing a shutter or generating voltage across particular nanocontacts.

Science has made progress along these lines: cells are remarkably efficient at catalyzing a wide range of chemical reactions (Ref 2) such as fermentation, respiration and photosynthesis, using a variety of electron donors and acceptors. Recently, researchers have been able to program cells in rudimentary ways to perform tasks not evolved in nature (Ref 3). Since several years ago researchers are able to couple natural biomachines with engineered materials to create a hybrid nanomachine (for one example see Ref 4). In addition, researchers have been able to use RNA reactions inherent to biomineralization pathways to catalyze mineralization reactions *in-vitro* (Ref. 5), and to use DNA or viruses to assemble nanocrystalline arrays (Ref. 6) and use biological pathways to create new engineered materials (Ref. 7). Researchers are also beginning to harness nature's self-assembly processes (Ref. 8).

The Problem

Your task is to create a scientific plan for using biological or biomimetic mechanisms to create one or more steps in a bio-nanoscale assembly process that could be scaled up to synthesize useful products in volume.

- First, the group should decide what the ultimate product is, such as, for example:
 - a. Create an engineered method of effective remediation of contaminated ground water, where the nanoproduct can learn what the dangerous contaminants are, grow the machinery to neutralize them, and then afterwards disassemble into environmentally friendly materials;
 - b. Create an engineered method for creation of 'smart' clothes that will sense the environment and automatically adjust their breathability, UV blocking ability, water repellency, toughness, cooling and heating or germicidal abilities; or,
 - c. Feel free to come up with your own grand challenge.
- Next, pick one or several limiting steps in the manufacture of such a product and come up with a scientific plan to potentially accomplish them, including what scientific knowledge or engineering prowess we currently lack, and thus would need to learn in order to accomplish this task. For example, in choice a) or b) above, how would one go about creating swimming devices or fibers that 'sense' the environment around them? What should be sensed? Once the environment is measured, what mechanisms, including feedback and control, would be relevant to react to that information? How does one deal with stochastic processes on the nanoscale?
- Finally, use the group's ingenuity to propose a plan for the manufacture in large volume of your product or sub-product, using biomimetic principles. As always, the group should discuss the ethical considerations in the manufacture of your products. How would one do the manufacture as safely as possible? What controls should be put in place?

Initial References

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- 4 - Soong et al., Powering an Inorganic Nanodevice with a Biomolecular Motor. Science, 2000. 290, pp.1555-1558.
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- 8 - Bowden, N. B., Weck, M., Choi, I.S. and Whitesides, G.M., Molecule-mimetic Chemistry and Meso-scale Self-assembly, Account of Chemical Research, 2001. 34, pp. 231-238.