Thematic Workshop B: "Probing the Interface between Biological Systems and the Environment"
Organizers: Stefan Vogt (APS), Tijana Rajh (CNM), Ed O'Loughlin (BIO)

The diverse and complimentary imaging and spectroscopic capabilities at the APS, CNM, and EMC provide unique tools to probe the highly complex interactions between biological systems and their environment. This workshop highlighted cutting-edge applications of multiple spectroscopic and imaging approaches to examine biological systems in the context of environmental processes (e.g., microbial respiration on insoluble electron acceptors, microbial interactions with and transformation of contaminants, biofilm development, and biomineralization processes, among others) with an emphasis on those that further the DOE mission of determining the biological and environmental impacts of energy production and use.

Matthew Marshall, a recipient of the 2011 DOE Office of Science Early Career Research Award from Pacific Northwest National Laboratory, presented his work using a multi-faceted, multi-scale approach employing a combination of synchrotron-based X-ray imaging and electron microscopy (EM) to construct a high spatial resolution, complex chemical image of a biofilm community in its nearest-to-native state. Conventional and cryogenic EM capabilities were correlated with X-ray imaging and nano-secondary ion mass spectroscopy (nano-SIMS) to produce high-sensitivity, element-specific distributions which correspond to EM images of the biofilm at the nanometer scale while synchrotron-based infrared imaging provided high spatial resolution images with spectral data showing the localizations of biofilm components (*i.e.*, proteins, nucleic acids, membrane lipids, etc.). Using the X-ray microtomography system at sector 2BM of the APS, biofilms of *Shewanella* grown on multiple substrates were imaged at energies ranging from 13-18 keV and spatial scales of 0.7 and 1.4 µm/pixel. Improved imaging was obtained when contrasting agents such as Os were added to enhance biofilm visibility.

Catherine Murphy of the University of Illinois at Urbana-Champaign spoke passionately about her work on noble metal nanoparticles that are used as a platform for studying nano-bio-eco interfaces at the molecular level. It was an exceptionally well-delivered presentation on many different facets of this research, including nanoparticle fabrication and functionalization, using gold nanorods for cellular imaging, chemical sensing, and photothermal therapies, and also touched on the environmental implications of using nanoparticles.

Jason Unrine of University of Kentucky discussed investigations of the transformation, bioavailability and adverse effects of Au, Ag, CeO_2 and Cu nanoparticles in soils, using both earthworms (*Eisenia fetida*) and nematodes (*Caenorhabditis elegans*) as model systems. In addition, they investigated the transfer of Au nanoparticles along simulated terrestrial food chains, and demonstrated the bioavailability and trophic transfer of nanoparticles from soil. X-ray fluorescence microscopy and micro X-ray absorption spectroscopy were essential for establishing the uptake and biodistribution of nanoparticles in tissues as well as their transformations in soils.

Ka Yee Lee of the Chemistry Department at the University of Chicago presented studies on the mechanism of structural transformations induced by antimicrobial peptides in lipid membranes. Learning the basic chemistry of these systems has implications for the successful application of lung surfactants to respiratory distress syndrome and the amyloid-beta peptide associations with Alzheimer's disease.

Ryan Tappero of Brookhaven National Laboratory reported on studies investigating the mechanisms of metal tolerance in metal hyperaccumulating plants, making use of both x-ray fluorescence microscopy to visualize metal distributions, as well as x-ray absorption spectroscopy (XAS) to probe local chemical state of the metal of interest. He and his collaborators discovered that the rudimentary plants contained within some seeds have the ability to compartmentalize metal for long-term storage.

Maxim Boyanov from the Biosciences Division at Argonne presented research highlighting the utility of combining high-resolution imaging and spectroscopic tools to understand the coupled biological-abiotic processes that control elemental transformations in subsurface environments. Electron microscopy (SEM and TEM) and synchrotron x-ray fluorescence microscopy and spectroscopy (XANES and EXAFS) were used to examine mechanisms of iron oxide secondary mineralization processes as well as microbially-mediated and abiotic electron transfer reactions controlling the solubility (and thus potential mobility) of uranium in uranium-contaminated environments.

Mark Jensen from the Chemical Sciences and Engineering Division at Argonne National Laboratory reported on research investigating protein-mediated uptake of plutonium by cells. He and his team used x-ray fluorescence microscopy as well as small angle scattering techniques to show that transferrin, which usually serves to transport iron into a cell, can also transport plutonium, if an iron-containing N-subunit is combined with a plutonium-containing C-subunit.

Chantel Tester from Northwestern University presented investigations to better understand the biological use of amorphous mineral precursors in biomineralization, to create single crystalline, yet composite materials with curving, branching shapes that are beyond current synthetic capabilities. A combination of techniques was used, including X-ray absorption spectroscopy to determine the local structure, simultaneous small- and wide- angle X-ray scattering to follow precipitation kinetics, and X-ray imaging to visualize growth rate. The formation and transformation of amorphous calcium carbonate both *in vivo* in sea urchin larval spicules and *in vitro* in liposome models of intracellular biomineralization was shown.