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NIRT: Biocatalytic Membrane Nanosystems (BMNs)

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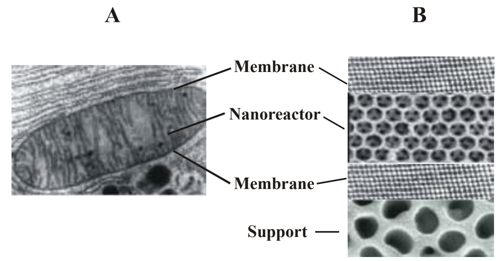
Recent advances in molecular engineering of ordered nanoporous materials with tunable surface chemistries and their integration into macroscopic architectures offer new, unprecedented opportunities to design highly efficient biomimetic systems for biocatalytic production of pharmaceuticals and other fine chemicals. Among such engineered materials, new nanoporous silicas templated by colloidal sphere arrays and containing ordered 20-100 nm voids are particularly promising hosts for enhancing the biocatalytic efficiency of current immobilized, encapsulated and microbial enzymatic processes, which suffer from a series of drawbacks, such as mass-transfer limitations, unpredictable behavior and the difficulty of handling living cells in a large-scale process. This research seeks to design ordered nanoporous silica layers containing encapsulated enzymes as part of Biocatalytic Membrane Nanosystems (BMNs). The fundamental scientific issues underlying the design of highly efficient BMNs will be addressed for two well-characterized and important enzymatic reactions: (1) kinetic resolution of achiral molecules by *Pseudomonas cepacia* lipase and (2) cofactor-dependent selective oxidation of non-activated carbons by cytochrome P450 BM-3 oxygenase. The research objectives of this research are:



Natural and biomimetic biocatalytic systems: (A) mitochondria and (B) proposed BMNs

- **Investigate the effects of confined nanoscale environment and surface chemistry of nanoporous silica on biocatalytic efficiency of encapsulated enzymes**
- **Develop fully integrated functioning BMNs for kinetic resolution of achiral molecules and oxidation of non-activated C-H bonds**

The proposed NIRT brings together four experts from the Colleges of Engineering and Pharmacy to address various fundamental and engineering issues related to the development of BMNs. Preliminary studies demonstrated that it is possible to tailor the porosities and surface chemistries of nanoporous silica layers required for the BMN development. The proposed research will investigate the effects of solution conditions (pH, ionic strength, temperature), pore morphology and surface functionality (type, density, grafting procedure, etc.) as well as cofactor and substrate concentration on the biocatalytic efficiency of enzymes in confined nanoscale environment of nanoporous silica. The biocatalytic efficiencies will be evaluated in terms of the enzyme activity, regio- and stereoselectivities, and pH-rate profile. The integration of various components into fully functioning prototype BMNs will be conducted in parallel with the fundamental studies employing nanoporous silica.

Intellectual Merit: The proposed BMNs possessing well-defined ordered nanoporous structures and surface chemistries will be uniquely suited for studying nanoscale structure-reactivity/selectivity relationships in kinetic resolution of achiral molecules and oxidation of non-activated carbons in organic molecules. This research will also lead to improved understanding of nanoscale structure and catalytic function of biomimetic systems and to the design of improved biocatalysts from basic scientific principles. If successful, this research will also suggest a generic synthetic motif for the development of functional structures for other applications in biocatalysis, bioseparations, and biosensing.

Broader Impacts: Another positive outcome of this NIRT research will be the education and training of undergraduate and graduate students in the area of molecularly engineered materials for biocatalytic applications. This will be accomplished in part by the outreach efforts directed towards improving higher education opportunities for minority and women engineers by alerting them to the graduate research opportunities at the University of Cincinnati (UC). Moreover, a new training program in *Biocatalysis* will be created that will enhance on-going NSF I/U CRC, REU and IGERT programs at UC in the area of membrane science. These efforts will be complemented by a new research effort on societal impacts of nanotechnology that will bring together the UC Institute for Policy Research, leading UC researchers and graduate students in social and physical sciences to develop a plan for integrating the social and technological aspects of nanotechnology. The proposed educational activities will promote interest of science and engineering students in molecular engineering and enhance their awareness of the impacts of new technologies on the chemical processing industry, environment and society.