M O N T A N A B O A R D O F R E G E N T S

LEVEL II REQUEST FORM

Item No.:	**136-2006-R0907**	**Date of Meeting:**	**September 19-21, 2007**
Institution:	**Montana State University-Bozeman**		
Program Title:	**Astrobiology and Biogeocatalysis Research Center**		

Level II proposals require approval by the Board of Regents.

Level II action requested (check all that apply): Level II proposals entail substantive additions to, alterations in, or termination of programs, structures, or administrative or academic entities typically characterized by the (a) addition, reassignment, or elimination of personnel, facilities, or courses of instruction; (b) rearrangement of budgets, cost centers, funding sources; and (c) changes which by implication could impact other campuses within the Montana University System and community colleges. Board policy 303.1 indicates the curricular proposals in this category:

- ☐ 1. Change names of degrees (e.g. from B.A. to B.F.A.)
- ☐ 2. Implement a new minor or certificate where there is no major or no option in a major;
- ☐ 3. Establish new degrees and add majors to existing degrees;
- ☐ 4. Expand/extend approved mission; and
- ☒ 5. Any other changes in governance and organization as described in Board of Regents' Policy 218, such as formation, elimination or consolidation of a college, division, school, department, institute, bureau, center, station, laboratory, or similar unit.

Specify Request:

Montana State University-Bozeman seeks authorization to create the MSU – Astrobiology and Biogeocatalysis Research Center (ABRC). The overall goal of the center is to pursue fundamental studies on prebiotic chemistry and explore the role for iron-sulfur compounds in the transition from the nonliving to the living world. The research bridges the disciplines of biochemistry and geochemistry and will train the next generation of scientists with a multi-disciplinary view of molecular catalysis. This broad-based training will be valued in basic and applied research settings.

The National Aeronautic and Space Administration has pledged more than six million dollars over a five year period to establish the center in the form of a competitively funded project to establish a node of the NASA Astrobiology Institute. The NASA NAI currently consists of 16 centers nationwide and includes institutes at: University of California at Berkeley, California Institute of Technology, Massachusetts Institute of Technology, NASA Ames Research Center and NASA Goddard Space Flight Center. The support for NASA Astrobiology Institute node and establishing an Astrobiology and Biogeocatalysis Research Center at Montana State University places MSU in an elite group.

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PURPOSE:

NASA has made a considerable investment in the study of origins, evolution, distribution and future of life in the universe through the establishment of its NASA Astrobiology Institute (NAI). The proposed center, the Astrobiology and Biogeocatalysis Research Center (ABRC), led by Montana State University will be a unique new node in NAI. The vision for the Center is to:

- develop a team-based, cross-disciplinary research agenda centered on the role of mineral catalysis in the origin of life and the transition to biocatalysis during the emergence of life;
- create a nurturing and stimulating environment for the training of the next generation of researchers in this field through the development of cross-disciplinary research teams, new education models, and career development opportunities for undergraduate and graduate students as well as postdoctoral research fellows;
- increase the visibility of Astrobiology at the undergraduate level and increase the number of underrepresented minorities in scientific disciplines, building on Montana State's close connections to tribal colleges;
- develop an outreach program organized around the astrobiology research activities and Yellowstone National Park that leverages existing programs at Montana State;
- develop an important role in the Astrobiology community by organizing symposia and workshops, hosting scientist from other NAI centers, and providing training and access to research facilities at MSU; and
- build an efficient management structure, including integration of contributing scientists at Stony Brook University and Temple University, and integration of the proposed center into the University structure at MSU.

From Mineral Catalysts to Biocatalysts.

The field of astrobiology or exobiology is the study of origins, evolution, distribution, and future of life in the universe. The examination of life in the most extreme environments on earth have provided us with a better appreciation of how life can exist in diverse environments, and can perhaps provide clues as to how life arose in an abiotic environment. One theme of these studies has been the realization that microbial life is remarkably evolved to a wide range of chemical and physical environments. Microbial life on earth is widely distributed, and certain microbes thrive at extremes of temperature, pH, and pressure. Some of these environments include the polar caps, deep ocean hydrothermal vents, and aqueous surface geothermal sites such as those present in Yellowstone National Park. Essential for the understanding the evolution of life on earth, and possibly on non-earth based bodies, is the knowledge of how precursors for life arose and were assembled from an abiotic setting. Such knowledge would prove invaluable for developing chemical signatures for detecting life beyond earth.

Specific Research Challenges: Overview

Research at the ABRC will focus on addressing and integrating the following challenges in biological, nanoscale, and mineral catalysis:

1. Detailed studies on biological Fe-S catalysts. In order to evaluate the connection among Fe-S-based catalysis in minerals, clusters, and biocatalysts, we propose to investigate
    - Biological mechanisms for Fe-S cluster synthesis and assembly, including the introduction of cluster modifications and their role in radical chemistry.
    - Structural and physical characterization of complex Fe-S cluster-containing enzymes.
    - Homogeneous (solution) catalytic properties of Fe-S cluster enzymes.

- Spectroscopic and computational analyses of Fe-S clusters in selected enzymes (nitrogenase, hydrogenase)

2. Investigation of catalysis at iron-sulfide mineral surfaces in aqueous and gas phase systems as models of prebiotic chemical transformations. Foci will include
   - Properties of synthetic mineralized surfaces
   - The impact of surface defects and modifications on the physical and catalytic properties of an iron-sulfur mineral surface
   - The effect of energy (photo, redox, thermal, mechanical), pH, concentration, partial pressure of gases, surface area, and length scale on the structural, physical, and catalytic properties of iron-sulfur clusters, particles and minerals, and materials studied by beam/surface collision experiments.
   - Spectroscopic analyses and structural modeling of mineral surface defects by integrated theoretical and computational methods.

3. Bridging the gap between Fe-S minerals and highly evolved biological Fe-S metalloenzymes.
   - Organic template (protein) mediated cluster assembly – *biomineralization.*
   - Properties of synthetic nanoclusters, both as homogeneous and heterogeneous catalysts.
   - The impact of size scale on the properties of synthetic iron-sulfur clusters and array.
   - Computational modeling of the structure and catalytic properties of synthetic iron-sulfur nanoparticles in the 5-50 nm range.

Academic Environment and Institutional Commitment

The proposed Astrobiology Research Center team involves investigators with expertise in geochemistry, experimental and theoretical physical chemistry, materials science, nanoscience, and the iron-sulfur cluster biochemistry. The P.I and a number of the Co-P.I.'s have been and are currently involved with University based research centers of excellence (Center for Biofilm Engineering, Center for Bioinspired Nanomaterials, and Thermal Biology Institute at MSU, and the Center for Environmental Molecular Science at Stony Brook) that can serve as excellent models for management structure as well as outreach and education. We will face a number of the same challenges in research training at the undergraduate and graduate level and in the public dissemination of information in these programs as we anticipate we will face in the Astrobiology Research Center. Montana State University and Stony Brook have a long-standing tradition of significant support of research centers fostering their individual success with dedicated lines for faculty hires and supplemental support for research and creative activities. Montana State University has made the ABRC a high scientific priority for the University and has pledged to dedicate two faculty lines to support the centers goals. Several team members will be located in the new chemistry building. This will be key to the institutional coherence of this center and ensure close working environment for the cross-disciplinary research and education proposed.

The Astrobiology and Biogeocatalysis Research Center will create an integrated multi-disciplinary environment for engaging student at all levels. Undergraduate, graduate, and post-doctoral training will occur at the level of catered coursework and multi-investigator/multi-institution research training experiences at Montana State, Temple, and Stony Brook. The subjects of astrobiology and the origin of life raise a number of ethical and philosophical issues that will be addressed in structured coursework.

Outreach and Public Education

Education and Public Outreach activities of the ABRC will take advantage of MSU's proximity to Yellowstone National Park, the thriving undergraduate research environment at MSU, and the

expertise, experience, and resources of the Thermal Biology Institute and the Montana Space Grant Consortium. Public Outreach efforts will be conducted through a *Building Blocks of Life* program, which will target 7th and 8th grade students with modules on prebiotic chemistry and understanding the conditions for early life. This program will also involve a substantial "Train the Trainers" element, working with park rangers, teachers, museum education personnel, and other education professionals. MSU students will be engaged in undergraduate research and outreach through the ABRC through an Astrobiology Outreach Fellows Program. Modeled on the successful outreach program of the Montana Space Grant Consortium and Montana Space Science Network Northwest, Astrobiology Outreach Fellows will be trained to deliver exciting and informative presentations to public school students throughout the state of Montana.

Management Plan

The ARBC will be led by an Executive Committee composed of leaders in the different research and education components. A University Oversight Committee and External Advisory Board will provide guidance on a regular basis. Videoconferencing and polycom technology will be used to hold regular distributed meetings with the other research sites. To insure that the Astrobiology Center addresses research and development issues of central importance, the Executive committee, with advice from the External Advisory Committee and the Astrobiology Center faculty, will follow a procedure for identifying seed funding, and inter-institutional collaboration opportunities, for implementing and evaluating the educational and outreach activities, and to ascertain needed infra-structure enhancements.

Commitment to Implementing the Collaborative and Networking Concepts of the NAI

The Thermal Biology Institute (TBI), the Center for Bioinspired Nanomaterials, the Montana Space Grant Consortium, and the ABRC will team to organize, host, and sponsor an annual meeting for the NAI community focused on integrating the disciplines of atmospheric science, life in extreme environments, and pre-biotic chemistry. This leverages the unique position of the ABRC within the context of the over-arching NAI mission.

The ABRC builds on some established interactions, in particular the collaborations of Professors Peters and Douglas, on template-constrained synthesis of metal-oxide and metal particles, and Professors Peters and Szilagyi in the area of physical and computational studies on iron-sulfur enzymes. A new senior faculty member, Joan Broderick, has recently joined the faculty at MSU with expertise iron-sulfur enzymes, and has initiated fruitful collaborations with the core research members. The newly established collaboration between Professors Broderick and Peters is a perfect marriage of their respective biochemical expertise in complex iron-sulfur enzyme structure and mechanism and iron-sulfur cluster based radical biochemistry. Dr. Schoonen and Strongin have collaborated for nearly a decade on studies related to the surface chemistry of sulfides. It features Stony Brook University faculty member, Dr. Parise, who has extensive expertise in characterization of amorphous materials and has collaborated with Dr. Schoonen on the characterization of amorphous FeS for the last two years. A longstanding collaboration between Professors Douglas and Young in the area the biomineralization and biomimetic synthesis of nanophase materials will continue as a key component of the Center.

Astrobiology Center Impact.

A major stimulus for building from individual collaborations to an Astrobiology Center is our vision of undertaking multidisciplinary research directed toward larger impact goals. As is becoming abundantly clear, the broader societal impact of the research performed at this Center and others like it must be gauged and discussed. The interaction with faculty from the Department of History

and Philosophy will focus their research on the societal impacts of research into the questions about the origin of life, evolution, and nanotechnology.

Broader Impacts.

The expanded vision of our efforts could translate into the initiation of high technology economic development for the region, an aspect of the university-based research effort that is sorely needed for Montana and the Northern Rocky Mountain region. Montana State University has a responsibility as the leading Science and Engineering institution in the state of Montana to be the leader in educational outreach in the sciences. We have established outreach efforts through partnerships with the Thermal Biology Institute, The Center for BioInspired Nanomaterials, the Museum of the Rockies, the Burns Telecommunications Center and Montana Space Grant Consortium to reach across the vast geographic region that we traditionally serve. In particular, we will target those communities without access to well-developed educational infrastructure (with particular emphasis on the tribal colleges throughout Montana). MSU has a well-established reputation for the successful development of rural, state, and regional economies. Therefore the broader impact of our approach in establishment and funding of this Center will not only have an international scientific impact, but will be felt in both the economic and educational outreach spheres, at the local and regional level.

Composition of the Astrobiology Team.

This proposed Center deepens the collaboration within a core of five scientists at Montana State University in three departments, incorporates strength in structural biology/enzymology, computational chemistry existing at MSU, and adds additional areas of complementary expertise from other institutes. The areas of expertise span bioinorganic enzymology, molecular biology, bioorganic and synthetic chemistry, physical and materials chemistry, spectroscopy, solid-state physics, and geochemistry.

John W. Peters, the PI and Director of the ABRC is Professor of Chemistry and Biochemistry and Director of Montana State University's Thermal Biology Institute. Peters' expertise is in the area of structure/function relationships in iron-sulfur enzymes where he has made a number of seminal contributions and written several invited reviews on the subject over the past decade. He has previously organized an ACS symposium on hydrogenases and biological hydrogen production. He recently served as the Chair and Organizer for the first Gordon Research Conference on Iron-Sulfur Enzymes which was held in June 2006 and will Chair the 16th International Congress on Nitrogen Fixation to be held June 2009 in Big Sky, MT.

Martin Schoonen is Associate Director of the ABRC, Professor of Geochemistry, and Associate Vice President for Research at Stony Brook University. Schoonen has been an active researcher in the area of mineral-based catalysis and surface chemistry of iron sulfides for nearly two decades. He has been conducting research on the role of mineral catalysis in prebiotic chemistry since the mid-90s. He has co-organized several ACS symposia on the subjects of mineral reactivity and prebiotic chemistry. He is currently Program-Chair Elect for the ACS-Geochemistry Division and serves on the Editorial Boards of Geochemical Transactions and Chem Geol.

Prasanta Bandyopadhyay is Associate Professor of Philosophy specializing in philosophy of science, which investigates into the nature and assumptions of scientific methodology and will contribute to the project by examining the validity of the kinds of methods used, assumptions made and results arrived at by our team while attempting to unravel the mystery regarding the origin of life. He was an invited speaker at the International Bayesian Statistics Conference held in Varanasi in 2005. He has been a referee for the PROGIC 2005 July conference held in London School of Economics and for the Oxford University Press for a comparative (East/West) book proposal on philosophy.

Joan B. Broderick is Associate Director of the Outreach and Education for the ABRC and Professor of Chemistry and Biochemistry at Montana State University. Her research expertise is in the area of bioInorg Chem, particularly the biological chemistry of iron-sulfur clusters. She has made seminal contributions to the mechanistic understanding of radical

SAM enzymes, a newly identified superfamily of iron-sulfur enzymes that catalyze radical reactions. She has served as the Chair for both the NIH Metallobiochemistry and Macromolecular Structure Function A Study Sections and was the Co-Chair and Organizer of the Twelfth International Conference on Biological Inorg Chem held in August 2005.

Trevor Douglas is Professor of Chemistry and Biochemistry and Director of MSU's Center for Bioinspired Nanomaterials. His area of expertise is in biomineralization, biomimetic approaches to nanomaterials synthesis, and the role of Fe in oxidative stress responses in hyperthermophilic archaea. He has recently organized an MRS symposium on biomimetic materials chemistry, an ACS symposium on Nanoparticles in the environment, and an international meeting on Viruses and Protein Cages as Materials. He and contributed significantly to the literature in these fields and presented his work at many national and international meetings, including 6 invited Gordon Research Conference lectures.

Timothy K. Minton is Professor of Chemistry and an experimental physical chemist in the Department of Chemistry and Biochemistry at Montana State University. He has world-renown expertise in the area of gas-surface reaction dynamics at hyperthermal energies. He will support the proposed research by studying the mechanisms by which nitrogen gas can be reduced at FeS_2 surfaces and how these mechanisms depend on collision energy, surface morphology, and surface doping. He is the Principle Investigator of the Montana State University "Center for Ground-Based Studies of Rocket Plume Chemistry." He is the organizer of an American Chemical Society Symposium, "Chemical Dynamics in Extreme Environments," to be held at the 232nd ACS National Meeting, September 10-14, 2006, in San Francisco and is currently the Senior Editor of the J Physical Chemistry A&B.

John B. Parise is appointed jointly in the Department of Geosciences and Chemistry Department, Stony Brook University. His expertise is in the area of crystallography and solid state chemistry, especially the characterization of shot range intermediate and long range order in microporous, nano-porous and nano-crystalline materials. Much of this work is performed at national synchrotron and neutron facilities where the increased brilliance allows time resolved studies of the formation and transformation of nano-crystalline materials through the use of total scattering techniques. He has previously served as Chair of both National Synchrotron Light Source Users Executive Committee and GeoSynch promoting the use of synchrotron radiation.

Daniel Strongin is Professor and Vice-Chairman of the Department of Chemistry at Temple University. His expertise is in the application of modern Surface science techniques to understand important issues in environmental chemistry and mineral driven chemistry. He has an active research program in the surface reactivity of iron sulfide mineral and nanoparticle surfaces. He has (co)organized ACS symposia in the areas of Mineral Catalysis, Spectroscopy of Mineral Surfaces, and Nanotechnology for Environmental Remediation.

Robert K Szilagyi is an Assistant Professor at the Chemistry and Biochemistry Department, Montana State University. He has extensive experience with multi-edge X-ray absorption spectroscopic techniques, XANES and EXAFS analysis. He complements his spectroscopic measurements with a broad range of computational chemical tools including empirical force field, semi-empirical, ab initio molecular orbital, and density functional theories. He was the organizer of a XANES/EXAFS workshop at the Advanced Light Source Users' Meeting in 2005 and currently serves as the Biophysical Users' Representative on the Stanford Synchrotron Radiation Laboratory User Executive Committee.

Mark A. Young is Professor of Microbiology and Plant Sciences at MSU, Director of the NSF EPSCoR Program for the state of Montana, and Co-Director of the Thermal Biology Institute. His expertise is virology. His research program focuses on the isolation and molecular characterization of viruses found in high temperature environments as well as the use of viruses (and other protein cages) as biotemplates for nanomaterials synthesis. He has contributed significantly to the literature in these fields. He has served as an elected Executive National Board member of the American Society for Virology, as an organizer for the National Virology Meetings, and as a keynote speaker at the 2005 Archaeal Gordon Research Conference.