Cellular Signaling and Community Structure in the Environment

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Research. Microbes drive processes in the Earth system far exceeding their physical scale, mediating significant fluxes in global biogeochemical cycles. Microbial behavior also affects soil development, water quality, and crop yields. The tools of synthetic biology have the potential to significantly improve our understanding of microbes' role in the Earth system and their interactions with more complex organisms (e.g., plants); however, these tools have not yet seen wide use because synthetically "programmed" microbes are hard to deploy into many Earth materials, the vast majority of which are physically heterogeneous. A group of faculty at Rice has recently developed the first class of volatile gas reporters that allows scientists to nondestructively study specific biological mechanisms in ecologically-relevant soils and sediments. These gas biosensors represent a completely new approach to biological studies in complex dense materials because they allow real-time, dynamic, in situ detection of gene expression in hard-to-image settings. They are useful for research in Earth system science (C and N cycling), biofuels and green chemical production (optimizing mixed cultures in complex feedstocks), environmental remediation (detection of toxic materials *in situ*), human health (horizontal gene transfer in soils and antibiotic resistance), and synthetic biology (robustness of DNA circuits in complex settings).

Peer Groups. No other research groups apply gas reporters in soils or other hard-to-image materials. Rice faculty are unique in their grounding in Earth system science, ecology, microbiology and synthetic biology and ability to span the full spectrum of length scales relevant to the biosphere.

Existing Strengths: (i) connects faculty across department and school boundaries ranging from ESCI, BIOS, ChBE and CEVE; (ii) critical mass of faculty across campus competitive for NRT training grant since it connects scientists working at disparate length scales (10^{-6} to 10^{6} meters) and complexity (pure cultures vs soil communities), (iii) faculty have a programmatic grant pending with the Keck Foundation (Masiello, Silberg, M. Bennett, G. Bennett); (iv) uniquely positioned to take leadership role through the development of a Rice-located, international short course; (v) area is poised to grow connections with industries related to greenhouse gas management, environmental remediation, pipeline management; (vi) synergistic with existing training programs, such as BCB, CEVE, EEB, ES, and SSPB; (vii) Rice has received some Shell support already and work is of interest to energy industry, (viii) synergistic with efforts related to ecological genomics in environmental settings, and water-related efforts.

Investments needed to achieve pre-eminence: (i) Support for an annual short course on the application of gas biosensors, which would help speed the implementation of our tools and would seed collaborations. We seek to form international teams including Rice faculty that address environmental problems that would benefit from new molecular technologies. (ii) Support for international connections beyond this course, *e.g.*, visitor fellowships including visitor housing, a long-term challenge at Rice. (iii) Matching funds for postdoctoral hiring. (iv) Support for a repository of gas reporting microbes to insure that Rice becomes synonymous with this new approach. (v) Establish transitional post-doc fellowship positions combining independent research and teaching. (vi) Faculty hiring in areas that are synergistic with existing faculty, such as microbial ecology, geomicrobiology, and ecosystem ecology. (vii) Research infrastructure such as access to a greenhouse and appropriate instrumentation for better connecting environmental science, biology, materials and relevant industrial collaborators. (viii) Strategically locate new faculty hires who build bridges between Earth science, Synthetic Biology, Microbiology, Plant Biology and Ecosystem Ecology.

Impact. An internationally advertised short course, microbe repository, and excellent research will bring unique international visibility to Rice and increased funding from industry/governmental agencies to support development and translation of new technology to diverse challenges related to sustainability. An internationally recognized group of researchers will address rapidly evolving societal needs by creating new biological knowledge and transferring new biotechnologies to researchers who are not well connected, ecologists, soil scientists, plant biologists, and synthetic biologists.