

FYRE First Year Research Experience

Dr. Hailiang Dong is looking for First Year students to become part his research projects through the new FYRE program.

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The overall objective of Dr. Dong's research program is to understand how and why microorganisms and geological media (rocks, minerals, water) interact and how we can study their mutual interactions to understand a range of biogeochemical processes on Earth (past and present). We employ a number of geological, mineralogical, geochemical, and microbiological techniques to study these processes.

Life in extreme environments—microbial ecology and ecosystem functions in hypersaline lakes and desert environments

The diversity of microorganisms in hypersaline environments is of growing interest. We employ a suite of geochemical and microbiological approaches to study microbial diversity and functions in hypersaline environments in China. In general, microbial diversity decreases as salinity increases, but other geochemical conditions are also important in controlling microbial diversity and activity. We have acquired multiple isolates that have optimal growth salinity of near NaCl saturation (25-30% NaCl). These isolates have exhibited extreme resistance to heavy metals, toxic compounds, and UV and gamma radiation. These isolates can be used as model organisms to study microbial survival and adaptation on other planets, such as Mars. Our recent efforts focused on certain groups of microorganisms and their functions in saline lake environments on the Tibetan Plateau, NW China, including ammonia-oxidizing bacteria and archaea (AOB and AOA), aerobic anoxygenic phototrophic bacteria (AAPB), and archaea. Our results show that AOB, AOA and AAPB are abundant and active in saline lakes and their community structure tends to respond to environmental conditions. The Tibetan saline lakes harbor unique archaeal communities that show similarity to those from deep marine sediments. These lakes also serve as ideal places to study the effect of global climate change on the biosphere.

Although in a geology department, Dr. Dong's lab uses a suite of microbiological techniques to study microbial diversity and functions such as cultivation of novel species from environmental samples, molecular fingerprinting of species identity from various extreme environments, and testing of their functions (such as UV and salt resistance etc).

Your role as an undergraduate student: You will work closely with graduate students in a modern lab setting to learn a variety of laboratory techniques including cultivation and molecular microbiology skills such as DNA/RNA extraction, PCR reactions, cloning and sequencing, phylogenetic tree construction, functional testing. There is a strong possibility that you may participate in field work in summer, if you are available and willing to do so.

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Sample Projects with Dr. Hailiang Dong, Professor of Geology

Nanoscience and nanotechnology – Effects of nanoparticles on biological systems

What is the biological and environmental impact of nanotechnology? Nanotechnology offers many promising opportunities to enhance our standard of living. At the foundation of the promise is the recognition that nanoscale materials exhibit properties not found in molecules or bulk materials. These “new” and unique properties may also have associated inherent risks. Concerns about the risks of nanotechnology are expressed, the reality is, we do not know, or have sufficient data to make a data based judgment. The goal of this project is to provide sufficient data to assess the risks or benefits of nanomaterials in biological systems and the environment. To that end, the proposed work begins with the process of developing and/or adapting techniques that can be used to study nanoparticle/biological system interactions. Because microbial system is simpler and easier to detect any effects than human or mammalian cells, the initial assessment will be the viability of the bacteria after the introduction of the nanomaterials. A variety of bacteria and nanoparticles will be examined. For bacteria/nanomaterial combinations that show strong interactions, imaging and trapping technique can be used to identify the possible mechanisms for the observed interactions. Preliminary data show that gold, clay, and silica nanoparticles reduce *E. coli* growth rate by approximately 80%. Geologists have known that natural nanoparticles have been in our environment for millions of years. Can man made nanotechnology cause subtle or dramatic shifts in biological ecosystems, with potentially positive and negative consequences? The project is a starting point for determining bacteria/nanoparticle interactions and the mechanisms and for developing/adapting the techniques to study these interactions.

We culture model microorganisms and synthesize or purchase solid nanoparticles. Then we perform experiments where the selected bacteria are exposed to various doses of different types of nanoparticles. By monitoring microbial growth over time (via microscopes or cultivation), we determine the effects of nanoparticles on biological systems.

Your role as an undergraduate student: You will work closely with graduate students in a modern lab setting to learn a variety of laboratory techniques including preparation of culture media, cultivation of microbes and characterization (cell counting by microscopy, monitoring cell growth/death in real time), synthesis of nanoparticles and characterization via X-ray diffraction, BET surface area analysis, and surface charge determination. You will perform experiments to quantitatively assess the effects of nanoparticles on microbial growth and survival. You will make presentations on-campus and at regional and national conferences.

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Sample Projects with Dr. Hailiang Dong, Professor of Geology

Clean up of contaminated soils in our nation!

As a result of ending of the cold war, U.S. Departments of Energy and Defense are faced with a new task of disposing tremendous amount of nuclear wastes. Huge metal storage tanks are used to dispose of these wastes but they are not permanent. When they are buried underground, they tend to leak with time. As a result, a plume of contaminants, including heavy metals and radionuclides along with organic compounds, migrates into our drinking water. Inorganic contaminants tend to adsorb onto mineral surfaces, particularly oxides and hydroxides. Coincidentally, negatively charged groundwater bacteria also stick to these mineral surfaces. The close contact between bacteria and the contaminants makes bacteria ideal candidate for bioremediation (clean up of these wastes). Most living things, including humans, gain energy by transferring electrons from electron donor (organic carbon such as food) to acceptor (such as oxygen, O_2). In anaerobic (oxygen-free) subsurface environment (many groundwater aquifers), bacteria have abundant organic carbon from organic contaminants, but lack O_2 for breathing. To survive, bacteria have to use oxidized forms of metals as electron acceptors in substitution for O_2 . In this electron transfer process and resultant change of oxidation state of a variety of metals, bacteria can immobilize U(VI), Mn(IV), Cr(VI), and Tc(VII). When these elements are immobilized, they are removed permanently from groundwater. For example, U(VI) is soluble in groundwater. But when U(VI) is reduced to U(IV), U(IV) will form a mineral, uraninite and is therefore removed from drinking water. Bacteria can also immobilize Cd, Cr, Ni, Pb and Zn as a result of oxidation state change.

Dr. Dong's laboratory routinely cultures anaerobic bacteria and studies mineral-microbe interactions. We use either bacteria directly or products of mineral-microbe interactions to remove heavy metals and radionuclides in drinking waters and soils. We perform laboratory experiments to study the metal-mineral-microbe interactions and characterize the products of such interactions with a variety of laboratory techniques.

Role of first-year students: Your role in this project will work with graduate students in cultivation of bacteria, preparation (synthesis) of minerals, and perform studies of mineral-microbe interactions. You will learn a number of techniques including: culture media preparation, wet chemistry to measure chemical composition and oxidation state of various elements, general laboratory skills (centrifuge, balance, autoclave, anaerobic glove box, gassing station), X-ray diffraction to identify minerals, and microscopes. You will make presentations on-campus and at regional and national conferences.