Microbes play an immense, and arguably essential, role in every geochemical cycle in our biosphere. They influence the composition and structure of our atmosphere, continents and oceans. Over the last thirty-five years, advances in genomics and other technologies have illuminated the microbial realm, fundamentally changing our understanding of microbial functional and physiological diversity, ecology, and evolution.

Even after decades of research, however, there are long-standing, fundamental questions regarding the nature and extent of microbial activity in situ. These questions can be addressed if we gain a better understanding of the microbial communities involved in a given process, the factors that govern their activity, and the emergent processes that result from their collective activity.

To address such questions, investigators are developing and employing technologies and methods to allow robust synoptic geochemical and microbial measurements over space and time. For example, advances in mass spectrometry, in situ sensors and sampling tools, and lab-based molecular approaches have yielded surprising new insights into the roles that common and rare organisms play in key geochemical cycles.

Here we present our recent development: the Autonomous Biogeochemical In-situ Sensor System (the ABISS), which is a computer-controlled geochemical and microbiological laboratory built onto an autonomous vehicle lander (AVL). The ABISS is designed to autonomously collect still frame and video images of the sampling site, analyze geochemical composition, and then collect fluid and sediment samples for *in situ* experiments and laboratory analyses. The ABISS consists of leading-edge sensor and communication technologies that we and others have developed including underwater mass spectrometers and isotope analyzers, and an “optical modem” that allows scientists to communicate with deep sea instruments at unprecedented speeds. Thus, for the first time, scientists will be able to re-program this remote laboratory by talking to the computer with a laser. They can also recover the data, including high-definition video, at broadband speeds. This is a tremendous advance over existing technologies. When complete, the ABISS will be the most technologically advanced autonomous seafloor observatory to date. It will also be an “open design” platform, which we hope will help bridge the gap in our knowledge about the role that microbes play in governing biogeochemistry and, ultimately, the geochemical "evolution" our biosphere.