Life at the Common Denominator: Mechanistic and Quantitative Biology for the Earth and Space Sciences

Tori M. Hoehler

Exobiology Branch, NASA Ames Research Center

The remarkable challenges and possibilities of the coming few decades will compel the biogeochemical and astrobiological sciences to characterize the interactions between biology and its environment in a fundamental, mechanistic, and quantitative fashion. The clear need for integrative and scalable biology-environment models is exemplified in the Earth sciences by the challenge of effectively addressing anthropogenic global change, and in the space sciences by the challenge of mounting a well-constrained yet sufficiently adaptive and inclusive search for life beyond Earth. Our understanding of the life-planet interaction is still, however, largely empirical.

A variety of approaches seek to move from empirical to mechanistic descriptions. One approach focuses on the relationship between biology and energy, which is at once universal (all life requires energy), unique (life "manages" energy flow in a fashion not seen in abiotic systems), and amenable to characterization and quantification in thermodynamic terms. Simultaneously, a focus on energy flow addresses a critical point of interface between life and its geological, chemical, and physical environment. Characterizing and quantifying this relationship for life on Earth will support the development of integrative and predictive models for biology-environment dynamics. Understanding this relationship at its most fundamental level holds potential for developing concepts of habitability and biosignatures that can optimize astrobiological exploration strategies and are extensible to all life.