Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
2010 Volume III: Geomicrobiology: How Microbes Shape Our Planet

Introduction

Microorganisms play many essential roles in the function and evolution of Earth systems, even being responsible for the oxygen in Earth's atmosphere and for much of the natural gas used to heat homes and fuel vehicles. Geomicrobiology explores the diverse habitats, metabolisms and functions of microorganisms that occur primarily outside of human and animal hosts. This includes microbes that thrive in the most extreme environments on Earth such as boiling volcanic hot springs, deep-sea vents, acid mine drainage, radioactive waste sites and in the deep underground, where sunlight does not serve as a primary source of energy. Geomicrobiology is a highly interdisciplinary field that encompasses geology, geochemistry, molecular biology and microbiology – all applied to the study of interactions between microorganisms and Earth systems over the full range of geologic time and spatial scales.

A student's first introduction to the microbial world is often within the context of microbes as germs or parasites that cause disease or other harm with their only beneficial role being that of the decomposers of organic matter in predominantly terrestrial ecosystems. Not only do these narrow definitions of microbial form, function and habitat leave out the wide array of roles that microbes play in shaping the planet, but they also fail to inform on the greatest source of biological diversity on Earth – microbial diversity, a great deal of which lies outside of the terrestrial realm and even beneath the ocean floor.

Of the three domains of life, two comprise exclusively single-celled and microscopic organisms – the Bacteria and the Archaea, which collectively make up a significant amount of Earth's total biomass, yet receive very little attention in K-12 science courses. The overarching goal of this seminar was to expand science curriculum content on microorganisms and geomicrobiological processes by providing new information, and to also reinforce teachers' comprehension of fundamental concepts and relevant background knowledge of chemistry, geology, microbiology and biochemistry.

Larger and multicellular organisms are often described in terms of their physical appearance and behaviors, whereas the single-celled prokaryotes (bacteria and archaea) are described in terms of their metabolic and biochemical diversity. Exploration of microbial diversity thus requires knowledge of basic chemistry and metabolism central to all cells and especially the concepts of electrons, electron flow, and reduction-oxidation (redox) reactions.

Regardless of the grade level at which unit content is taught, it is highly beneficial for instructors to have a firm grasp of the underlying fundamental chemical/biochemical processes that govern metabolism and are common to all living organisms. Such fundamental background information was included in the seminar with the goal of enriching the teaching of specific unit content on geomicrobiology as well as enhancing the teaching of related science curricula. Units by Carol Boynton and Deborah James include detailed background

sections reviewing fundamental concepts in chemistry, energy flow and metabolic diversity. Haifa Abdel-Jalil emphasizes the physiological features of bacteria such as cell morphology, motility and reproduction as well as the many impacts of microbes on society.

One of the greatest challenges to teaching about microorganisms and microbial processes at the K-12 level, especially in the earlier grades, can be the lack of microscopes in the classroom needed to observe microbes and make them "real" for the students. Thus, hands-on activities included in several of the units (K-6 especially) emphasize macroscopic manifestations of microbial activity such as microbial mat communities (Deborah James, Melissa Talarczyk), root nodules and bioluminescence (Julia Biagiarelli), and the impact of microbial cycling of nutrients on other organisms as well as on humans (all units). Units by Charlene Woodland and Julia Biagiarelli include activities involving the detection of microbial activity through means other than direct visual observation of cells, such as the sense of smell and chemical detection of microbial metabolic byproducts.

Units emphasize both the helpful and harmful roles that microbes play in their interactions with other organisms and humans, with Melissa Talarczyk and Julia Biagiarelli focusing on the local marine habitat of Long Island Sound. The unit by Charlene Woodland considers the presence of microorganisms and their interactions with the Earth from its very beginnings.

Several of the units cover similar and common topics such as photosynthesis and the carbon, nitrogen (e.g., Boynton, Biagiarelli, Woodland) and sulfur (James, Woodland) cycles, but from different perspectives and at different depths appropriate to each grade level. This approach provides reinforcement of the more technical aspects and fundamental chemical concepts included in the seminar, so that, for example, a middle- or high-school instructor could benefit from the units written for K-2 students and vice versa.

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