# Interactions between microorganisms and extracellular minerals

With the support from the National Natural Science Foundation of China, the research team led by Prof. Dong Hailiang (**董海良**) at China University of Geosciences-Beijing, discovered the mechanisms of electron transfer between soil minerals and microorganisms, which was published in *Nature Reviews Microbiology* in October 2016, *Nature Communications* in 2012, and in *Science* in 2004.

Common soil minerals, such as metal oxides and clay minerals, can interact with soil microorganisms by transferring electrons between minerals and cells in reduction-oxidation reactions. As a consequence, soil minerals change their physical and chemical properties, thus affecting nutrient retention and soil fertility. Microorganisms gain energy from such reactions and grow. In many cases the microbial cell envelope is not physically permeable to minerals, nor is it electrically conductive. So some microorganisms have evolved strategies to exchange electrons with extracellular minerals. In the 2016 *Nature Reviews Microbiology* paper, Dong's team outlines recent advances in understanding the mechanisms that allow this electron exchange including: the molecular identification and functional characterization of representative electron transfer pathways; the discovery of electron transfers over long distance (centimeters); the suggestion that electron transfer pathways are bidirectional; the direct transfer of electrons between microbial cells using nanowires or multicellular "cable bacteria".

Dong's team has been studying mineral-microbe interactions for the past 15 years. In 2004, his team demonstrated for the first time that microorganisms can promote the reaction of smectite to illite, two common minerals in soils and sediments, by dissolving smectite through reduction of structural Fe(III) at room temperature and 1 atmosphere within 14 days. This reaction typically requires conditions of 300° to 350 ℃, 100 megapascals, and 4 to 5 months in the absence of microbial activity. These results, published in *Science*, have important implications for agriculture, petroleum industry, and materials sciences, because this reaction affects nutrient retention and soil fertility in soil, temperature-pressure prediction of petroleum maturation, and material synthesis via biotechnology. Subsequently, in 2012, Dong and his collaborators in a *Nature Communication* paper demonstrated for the first time that visible light-excited photoelectrons from metal oxide, metal sulfide, and iron oxide stimulated the growth of chemoautotrophic and heterotrophic bacteria. Similar observations were obtained in a natural soil sample containing both bacteria and semiconducting minerals. Results from this study provide evidence for a newly identified, but possibly long-existing pathway, in which the metabolisms and growth of non-phototrophic bacteria can be stimulated by solar light through photocatalysis of semiconducting minerals.

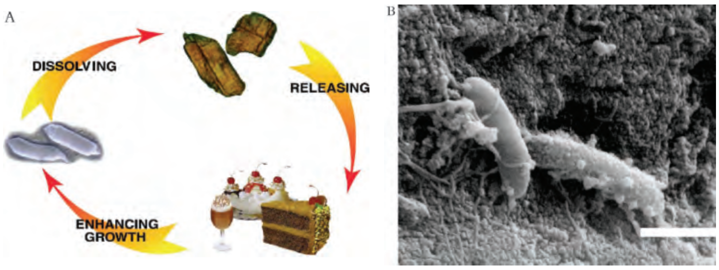

**Figure** A. Schematic diagram showing mineral-microbe interactions. Microbes dissolve minerals and release nutrients to support their growth. B. Scanning electron microscope (SEM) photomicrograph of rod-shaped cells on basalt surface. Scale bar is 0.5 μm. From Dong 2012.

These research results have potential for environmentally sustainable biotechnological applications. Some bioremediation technologies are already using such microbes to eat or degrade pollutants in soils, sediments, or groundwater. Biominінguses microbes to leach desired elements from low-grade ores in a less polluting and more energy-efficient way relative to current chemical methods. Microbe-mineral interactions also suggest potential applications in catalysis, semiconductor manufacture, low-power microbial fuel cells, cancer treatment, and the production of clean biofuels and clever nanomaterials.