Over the past century, the significance of the rhizosphere has been increasingly recognized by the scientific community. This complex biological system is comprised of vast interconnected networks of microbial organisms that interact directly with their plant hosts, including archaea, bacteria, fungi, picoeukaryotes, and viruses. The rhizosphere provides a nutritional base to the terrestrial biosphere, and is integral to plant growth, crop production, and ecosystem health. There is little mechanistic understanding of the rhizosphere, however, and that constitutes a critical knowledge gap. It inhibits our ability to predict and control the terrestrial ecosystem to achieve desirable outcomes, such as sustainable bioenergy production, crop yield maximization in diverse biogeographical environments, and soil-based carbon sequestration.