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Microbial Life in Soil - Linking Biophysical Models with Observations

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Microbial life in soil occurs within fragmented aquatic habitats formed in complex pore spaces where motility is restricted to short hydration windows (e.g., following rainfall). The limited range of self-dispersion and physical confinement promote spatial association among trophically interdepended microbial species. Competition and preferences for different nutrient resources and byproducts and their diffusion require high level of spatial organization to sustain the functioning of multispecies communities. We report mechanistic modeling studies of competing multispecies microbial communities grown on hydrated surfaces and within artificial soil aggregates (represented by 3-D pore network). Results show how trophic dependencies and cell-level interactions within patchy diffusion fields promote spatial self-organization of motile microbial cells. The spontaneously forming patterns of segregated, yet coexisting species were robust to spatial heterogeneities and to temporal perturbations (hydration dynamics), and respond primarily to the type of trophic dependencies. Such spatially self-organized consortia may reflect ecological templates that optimize substrate utilization and could form the basic architecture for more permanent surface-attached microbial colonies. Hydration dynamics affect structure and spatial arrangement of aerobic and anaerobic microbial communities and their biogeochemical functions. Experiments with well-characterized artificial soil microbial assemblies grown on porous surfaces provide access to community dynamics during wetting and drying cycles detected through genetic fingerprinting. Experiments for visual observations of spatial associations of tagged bacterial species with known trophic dependencies on model porous surfaces are underway. Biophysical modeling provide a means for predicting hydration-mediated critical separation distances for activation of spatial self-organization. The study provides new modeling and observational tools that enable new mechanistic insights into how differences in substrate affinities among microbial species and soil micro-hydrological conditions may give rise to a remarkable spatial and functional order in an extremely heterogeneous soil microbial world