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Colonization of a pristine soil environment – Microbial migration into micro-engineered Soil Chips buried in field soils

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Despite their fundamental importance, soils and their complex microbial communities have been one of the most difficult habitats to study, and past approaches have relied on reductionist black-box approaches. Microfluidic and micro-engineered model systems allow us now for the first time to address questions about soil habitat structure and microbial interactions in a complex environment at the microscale. We developed custom-designed "Soil Chips" that contain channels and obstacles on the micrometer scale, constructed in a transparent and gas-permeable silicone rubber that can be colonized by microbes.

Very little is known about how soil microorganisms interact in situ in the soil environment, as well as how they spread over distances of millimeters to centimeters. We buried custom-designed soil chips into field soil beneath deciduous trees. The chips were open for colonization from one side and contained a 4 x 8 cm wide arena where different habitat structures were simulated. The soil chips were either empty (air-filled), filled with water, or with a malt nutrient medium. After two months in field, we recovered the chips and immediately analyzed them microscopically.

We found that air-filled chips were more thoroughly colonized by fungi than the liquid filled ones. Different fungal species displayed different morphological traits; highly branching species rarely colonized further than the entry system of the chips, whereas guerilla-type species grew a few far reaching separate hyphae that colonized channels throughout the whole chip. Bacteria colonized the chips everywhere when chips were filled with a liquid phase, and addition of a nutrient medium caused higher cell numbers in channels. We also observed that organisms of higher trophic levels such as protists and nematodes where present in the chips, and we could observe soil aggregate formation and bacteria moving along water bridges on fungal hyphae, "fungal highways",.

Our soil chip system can help understand soil organic matter dynamics such as physical soil carbon stabilization, as the mobility of microorganisms in soil influences their ability to reach organic matter for degradation, and the distribution of their necromass is important for build-up of new soil organic matter.