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Build your own soil: Micro-engineered Soil Chips allow investigation of the role of habitat structure for microbial processes

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Soils are likely the most complex and species-dense ecosystems on earth. Microorganisms live in a world of soil pore labyrinths where resources and shelters are unevenly distributed among winding paths and dead end streets. The physical laws that dominate this world at the microscale are unintuitive for us, and it has long been difficult to investigate the effect of these microstructures when studying soil microbial processes.

Inspired by findings from soil pore space tomography and microbial colonization of biochar particles, we developed micro-structured growth habitats which we call Soil Chips using lab-on-a-chip techniques. We computer-designed complex environments with channels and obstacles at the dimensions of microbes, and constructed them from a transparent, gas-permeable silicone rubber. We can further fill our chips with different nutrient conditions or combine mineral nutrient gradients and patches inside the chips, and inoculate with soil organisms. We use them to study among other things; fungal foraging strategies, microbial colonization of pristine habitats, and the effect of the physio-spatial distribution of organic matter. We analyze organisms and substrates through bright field and fluorescence microscopy (ImageJ analysis) as well as analytical chemistry.

We compared different soil litter decomposers and an arbuscular mycorrhizal fungus in their ability to colonize nutrient-free soil environment as they foraged through complex air-gap structures. We identified structures which were difficult to penetrate for most species, which lead us to conclude that compounds located behind such features may thus be spatially unavailable for decomposers. We also let natural soil microbial communities colonize pristine soil models by incorporating them into natural soil ecosystems. In addition to fungi and bacteria, other trophic levels of soil microorganisms entered the systems, such as different protists and nematodes. The colonization ability of the different microorganism classes depended on both physical conditions (nutrient and water accessibility), but also on the presence or absence of other groups of organisms, with observations of phenomena such as hyphae acting as “fungal highways” for bacteria into the chips.