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Namibian and Australian fairy circles showcase basic principles of pattern-formation theory

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A most conspicuous aspect of water-limited ecosystems, or drylands, is their patchy vegetation. Vegetation patchiness is affected by microtopography and soil heterogeneities, but is also observed in fairly homogeneous areas. A striking example is the “fairy circles” phenomenon. Fairy circles are circular bare soil gaps in grasslands that form nearly periodic gap patterns on large scales. They have been observed and studied mostly in western Namibia, and, recently, have also been found in northwestern Australia. In this talk I will introduce the self-organization hypothesis according to which the large-scale order of the observed fairy-circle patterns is a result of positive feedback loops between local vegetation growth and water transport towards the growth location. Using mathematical models that capture these feedback loops, I will relate empirical observations to three principles of pattern formation theory: (i) symmetry breaking, i.e. the appearance of periodic hexagonal patterns in homogeneous systems, which will be related to the observations of six equidistant circles (on average) surrounding each circle, (ii) universality, i.e. the appearance of similar patterns in systems that differ in their mechanisms of pattern formation, which will be related to the different soil types in Namibia (sandy) and in Australia (claypan), (iii) transitions between hybrid states, i.e. mixed states involving domains of both uniform vegetation and periodic patterns, which will be used to account for processes of fairy-circle birth and death. The empirical manifestations of these pattern-formation principles provide strong support for the biomass-water self-organization hypothesis. I will conclude by confronting this hypothesis with a competing hypothesis based on termite dynamics.

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