TUT 3: Tutorial: Patterns in Nature and Materials (DY/BP/CPP)

Pattern formation and self-organization in nature fascinates both the layman and reseachers from many disciplines. In addition to their aesthetic appeal, the function of the patterns in nature are of central interest. Therefore, function, variability and control of patterns are a focus of current research.

This tutorial is intended to give especially young scientists the opportunity to learn more about the subject of (nonlinear) pattern formation. Besides the introduction of fundamental and universal concepts in the field, examples from various disciplines of natural science and materials research will be presented.

Time: Sunday 16:00–18:30 Location: HSZ 04

Tutorial TUT 3.1 Sun 16:00 HSZ 04
The fascination of pattern formation: Basic principles, applications, future directions — •Walter Zimmermann — Theoretische Physik I, Universität Bayreuth, 95440 Bayreuth, Germany

Self-organization and pattern formation are fundamental strategies in nature. In this talk I will give an introduction to the field and explain some main concepts with experiments. Using several examples from physics, biology or material science, I will illustrate that the mechanism driving a spatially extended pattern, like a stripe or traveling wave pattern, are vastly different in diverse systems. However, are there also common features in, for example, cloud streets, Turing patterns, wrinkles or stripes in active matter and fluids? I will explain that each nonlinear pattern has a number of robust and system-independent properties and that the concepts of pattern formation provide a theoretical framework for their generic properties. Why are patterns of different wavenumbers stable in homogeneous systems (variability)? By which generic principles can a pattern be selected or controlled? How do patterns interact with their environment such as boundaries or inhomogenities? Which functions do patterns in nature fulfill? Besides addressing these elementary questions, I will also highlight recent developments in the field, applications in emerging fields and possible future directions of pattern formation.

Tutorial TUT 3.2 Sun 16:50 HSZ 04
On growth and forms in nature — •Chaouqi Misbah — Laboratoire Interdisciplinaire de Physique, CNRS and Universite Alpes, Grenoble, France

Atoms and molecules self-assemble into fascinating patterns, such as snowflakes, that even very complex entities, such as biological cells and living micro-organisms, try to mimic despite their internal much higher complexity. This points to the existence of an intricate hierarchy of universality which still escapes today a comprehensive description. This lecture will present the basic rules and principles that lead to diverse non-equilibrium patterns and shapes in nature.

C. Misbah, Complex Dynamics and Morphogenesis: An Introduction to Nonlinear Science (Springer, 2016)

Tutorial TUT 3.3 Sun 17:40 HSZ 04
What can pattern formation theory tell us about ecosystem response to climate change? — •Ehud Meron — Ben-Gurion University, Beer-Sheva, Israel

Dryland landscapes show a variety of vegetation pattern-formation phenomena; banded vegetation on hill slopes and nearly hexagonal patterns of bare-soil gaps in grasslands are two striking examples. Vegetation pattern formation is a population-level mechanism to cope with water stress. It couples to other response mechanisms operating at lower and higher organization levels, such as phenotypic changes at the organism level and biodiversity changes at the community level, and plays a crucial role in understanding ecosystem response and ecosystem function in changing environments. In this talk I will present a platform of mathematical models for dryland ecosystems and describe some of the ecological questions we have studied using this platform. I will discuss the mechanisms that destabilize uniform vegetation and lead to periodic vegetation patterns, the variety of extended and localized patterns that can appear along a rainfall gradient, the impact of pattern-forming instabilities and front dynamics on state transitions (regime shifts), and restoration of degraded landscapes as a spatial resonance problem. I will conclude with a discussion of a major problem in our current era, the Anthropocene, namely, how to reconcile human intervention in ecosystems dynamics with ecological integrity.

E. Meron, Nonlinear Physics of Ecosystems, CRC Press 2015.
E. Meron, Pattern formation – A missing link in the study of ecosystem response to environmental changes, Mathematical Biosciences 271, 1 (2016).