Symposium Patterns in Nature: Origins, Universality, Functions (SYPN)

jointly organized by
the Dynamics and Statistical Physics Division (DY),
the Biological Physics Division (BP),
the Chemical and Polymer Physics Division (CPP), and
the Physics of Socio-economic Systems Division (SOE)

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Pattern formation and self-organization in nature fascinates both the layman and reseachers from many disciplines. Each type of self-organized pattern may occur in many different systems, but the fascinating driving mechanisms of self-organized (mostly dissipative) pattern can be as diverse as the systems in which they occur (origins). This raises among others the question about fundamental and common universal properties of patterns shared by different systems - from small cells and the collective behavior of active colloidal particles up to ecological or fluid dynamical (geological) scales? Which functions play universal nonlinear properties of patterns in nature? Are there common strategies for controlling spatio-termporal patterns?

Overview of Invited Talks and Sessions

(Lecture hall H1)

Invited Talks

SYPN 1.1	Mon	15:00–15:30	H1	**Engineering spatial-temporal organization of bacterial suspensions** — •Igor Aronson
SYPN 1.2	Mon	15:30–16:00	H1	**Collective behaviour and pattern formation in phoretic active matter** — •Ramin Golestanian
SYPN 1.3	Mon	16:00–16:30	H1	**Control and selection of spatio-temporal patterns in complex systems** — •Svetlana Gurevich
SYPN 1.4	Mon	16:45–17:15	H1	**Self-organization of Active Surfaces** — •Frank Jülicher
SYPN 1.5	Mon	17:15–17:45	H1	**Front instabilities can reverse desertification** — •Ehud Meron, Cristian Fernandez-Oto, Omer Tzuk

Related Sessions (exemplarily)

DY 3.1–3.11	Mon	9:30–12:45	H20	**Active Matter A (joint session DY/CPP)**
DY 5.1–5.9	Mon	10:00–12:45	H3	**Convection**
DY 15.1–15.12	Tue	10:00–13:15	H3	**Pattern Formation**
DY 20.1–20.7	Tue	14:00–15:45	H3	**Active Matter B (joint session DY/CPP)**
BP 13.1–13.12	Wed	9:30–13:00	H4	**Active matter I (joint session BP/CPP/DY)**
DY 32.1–32.15	Wed	15:00–19:15	H3	**Complex Fluids and Soft Matter (joint session DY/CPP)**

Related Plenary and Invited Talks (exemplarily)

PRV II	Mon	13:15–13:45	H1	**Ultimate Rayleigh-Bénard and Taylor-Couette turbulence** — •Detlef Lohse
PLV II	Mon	14:00–14:45	H1	**Self-propelled topological defects in biological systems** — •Julia M Yeomans
PLV IV	Tue	8:30– 9:15	H1	**Impact of Turbulence on Cloud Microphysics** — •Eberhard Bodenschatz
BP 33.1	Fri	12:30–13:15	H1	**Pattern formation in active cytoskeletal systems** — •Andreas R. Bausch

SYPN 1: Patterns in Nature: Origins, Universality, Functions

Time: Monday 15:00–17:45 Location: H1

Invited Talk SYPN 1.1 Mon 15:00 H1
Engineering spatial-temporal organization of bacterial suspensions — •Igor Aronson — Pennsylvania State University

Suspensions of motile bacteria or synthetic microswimmers, termed active matter, manifest a remarkable propensity for self-organization and formation of large-scale coherent structures. Most active matter research deals with almost homogeneous in space systems and little are known about the dynamics of active matter under strong confinement. I will talk on experimental and theoretical studies on the expansion of highly concentrated bacterial droplets into an ambient bacteria-free fluid. The droplet is formed beneath a rapidly rotating solid macroscopic particle inserted in the suspension. We observed vigorous inability of the droplet reminiscent of a supernova explosion. The phenomenon is explained in terms of continuum first-principle theory based on the swim pressure concept. Furthermore, we investigated self-organization of a concentrated suspension of motile bacteria Bacillus subtilis constrained by two-dimensional (2D) periodic arrays of microscopic vertical pillars. We show that bacteria self-organize into a lattice of hydrodynamically bound vortices with a long-range antiferromagnetic order controlled by the pillars* spacing. Our findings provide insights into the dynamics of active matter under extreme conditions and significantly expand the scope of experimental and analytic tools for the control and manipulation of active systems.

Invited Talk SYPN 1.2 Mon 15:30 H1
Collective behaviour and pattern formation in phoretic active matter — •Ramin Golestanian — Max Planck Institute for Dynamics and Self-Organization, Göttingen — University of Oxford

Suspensions of active particles that main their non-equilbrium state via phoretic mechanisms provide an enthralling system as the very mechanism that gives rise to single-particle activity also controls the interaction between particles at a long range. I will discuss consequences of such interaction using a number of examples, and demonstrate how various modes of interaction can compete to give us interesting instabilities and patterns. For the specific of magnetically active bacteria, I disucss how competition between an external shear flow and the magnetic alignment can lead to pattern formation.

Invited Talk SYPN 1.3 Mon 16:00 H1
Control and selection of spatio-temporal patterns in complex systems — •Svetlana Gurevich — Institute for Theoretical Physics, University of Münster, Wilhelm-Klemm-Str. 9, 48149 Münster, Germany

In the field of nonlinear dynamics, the control and engineering of the dynamical behavior of spatio-temporal patterns in complex systems is one of the key issues of recent research. In recent years, detailed experimental evidence and theoretical understanding of self-organization phenomena in the animate and inanimate world has been accumulated. This opens the way for the manipulation and control of existing systems. A variety of different control methods has been developed within the last decades. In particular, external periodic forcing methods as well as feedback loops have been widely used to influence the dynamics of patterns. In this talk, using a combination of theoretical, numerical and path-continuation methods we discuss how these control strategies can be applied to a different systems ranging from surface coating to laser dynamics problems. In particular, we focus on a theoretical description of experimental techniques such as dip-coating or vapor deposition of molecules that are often used for the coating of surfaces with a precise density and structure. We shall show how the basic properties of different systems lead to the formation of specific self-organized patterns. This enables the development of methods to control structure formation, e.g. by pre-structured substrates or external time-dependent fields.

15 min. break

Invited Talk SYPN 1.4 Mon 16:45 H1
Self-organization of Active Surfaces — •Frank Jülicher — Max-Planck Institut für Physik komplexer Systeme, Nöthnitzerstr. 38, 01187 Dresden

Biological cells are active systems and exhibit complex dynamic behaviors such as cell division, cell polarity establishment and cell locomotion. Such dynamic processes emerge from the collective interplay of many molecular components far from thermodynamic equilibrium. Active molecular processes such as the force generation of molecular motors along filaments of the cytoskeleton transduce chemical free energy to generate movements and mechanical work. I will discuss the self-organization of active surfaces in different geometries as models for the dynamics of the cell cortex. Self-organised active surfaces provide minimal models for the generation of shape and the emergence of dynamic patterns in basic cellular processes.

Invited Talk SYPN 1.5 Mon 17:15 H1
Front instabilities can reverse desertification — •Ehud Meron[1,3], Cristian Fernandez-Oto[2], and Omer Tzuk[3] — [1]Department of Solar Energy and Environmental Physics, BIDR, Ben-Gurion University of the Negev, Sede Boqer Campus, 8499000, Israel — [2]Complex Systems Group, Facultad de Ingenieria y Ciencias Aplicadas, Universidad de los Andes, Santiago, Chile — [3]Physics Department, Ben-Gurion University of the Negev, Beer-Sheva 8410501, Israel

Degradation processes in living systems often take place gradually by front propagation. An important context of such processes is loss of biological productivity in drylands or desertification. Using a dryland-vegetation model, we analyze the stability and dynamics of desertification fronts, identify linear and nonlinear front instabilities, and highlight the significance of these instabilities in inducing self-recovery. The results are based on the derivation and analysis of a universal amplitude equation for pattern-forming living systems for which nonuniform instabilities cannot emerge from the non-viable (zero) state. The results may therefore be applicable to other contexts of animate matter where degradation processes occur by front propagation.