Symposium Stochastic Dynamics of Growth Processes in Biological and Social Systems (SYGP)

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

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Stochastic dynamics of growth processes have been considered in great detail for physical systems in the past. Currently, there is significant and increasing interest on similar processes in adjacent disciplines, for example in the context of cancer modeling, in growing bacterial populations or in the formation of social communities. Talks at this symposium will discuss physics-based methods with which to study these phenomena, and how these methods can be applied to questions in biology and economics.

Overview of Invited Talks and Sessions

(Lecture room: HSZ 02)

Invited Talks

SYGP 1.1	Thu	15:00–15:30	HSZ 02	**Noisy invasions: large fluctuations in stochastic invasion models** — •Baruch Meerson
SYGP 1.2	Thu	15:30–16:00	HSZ 02	**Fractal clustering of inertial particles in random velocity fields** — •Bernhard Mehlig, Kristian Gustavsson
SYGP 1.3	Thu	16:00–16:30	HSZ 02	**Stochastic population dynamics on rugged fitness landscapes** — •Joachim Krug
SYGP 1.4	Thu	16:45–17:15	HSZ 02	**Modeling cancer as a stochastic process** — •Tibor Antal
SYGP 1.5	Thu	17:15–17:45	HSZ 02	**Von Neumann's growth model: from statistical mechanics to cell metabolism** — •Andrea De Martino

Sessions

SYGP 1.1–1.5	Thu	15:00–17:45	HSZ 02	**Symposium SYGP: Stochastic Dynamics of Growth Processes in Biological and Social Systems**

SYGP 1: Symposium SYGP: Stochastic Dynamics of Growth Processes in Biological and Social Systems

Time: Thursday 15:00–17:45 Location: HSZ 02

Invited Talk SYGP 1.1 Thu 15:00 HSZ 02
Noisy invasions: large fluctuations in stochastic invasion models — •Baruch Meerson — Racah Institute of Physics, Hebrew University of Jerusalem, Jerusalem 91904 Israel

Invasion fronts have been recognized as important, and often fateful, phenomena in ecology, epidemiology and biological evolution. The position of an invasion front fluctuates because of the shot noise of individual reactions. What is the probability to observe, at a given time, a front displacement that is considerably smaller or larger than that predicted from deterministic theory? The answer strongly depends on whether the front propagates into a metastable or unstable state, and I will review recent theoretical progress in both cases. The progress is mostly based on a dissipative version of WKB theory which assumes many individuals in the front region. In this theory the most likely history of the system, for a given front displacement, is encoded in a special trajectory of the underlying effective Hamilton mechanics, a classical field theory. This special trajectory is described by a traveling front solution. For fronts, propagating into unstable states, very large front displacements are much more likely than very small ones. The leading contribution to the probability density of a large displacement comes from a few fastest particles running ahead of the front. For such fronts the WKB theory breaks down, and new methods are needed.

Invited Talk SYGP 1.2 Thu 15:30 HSZ 02
Fractal clustering of inertial particles in random velocity fields — •Bernhard Mehlig and Kristian Gustavsson — Department of Physics, University of Gothenburg, 41296 Gothenburg, Sweden

Independent particles suspended in incompressible turbulent or randomly mixing flows may cluster together even though incompressible flows exhibit no sinks. This is an inertial effect: inertia allows the particles to detach from the flow. Distinct mechanisms have been invoked to explain clustering in incompressible flows. The two most common ones are "preferential concentration" and "multiplicative amplification". Preferential concentration refers to the tendency of heavy particles to avoid vortical regions of the flow. Multiplicative amplification, by contrast, explains clustering in terms of the logarithmic amplification of the sequence of many small kicks that the suspended particles experience.

In order to quantify the relative importance of the two mechanisms it is necessary to compute the fluctuations of the flow-velocity gradients that the particles experience as they move through the flow. We show how this can be achieved systematically by means of perturbation expansions that recursively take into account how the flow affects the actual particle trajectory. We analyse the statistics of particle- and flow-velocity gradients as seen by the particles. Based on these results we show that in random velocity fields multiplicative amplification has a much stronger effect than preferential concentration, except at very small Stokes numbers. We discuss the implications of these findings for particles suspended in turbulent flows.

Invited Talk SYGP 1.3 Thu 16:00 HSZ 02
Stochastic population dynamics on rugged fitness landscapes — •Joachim Krug — Institut für Theoretische Physik, Universität zu Köln

Biological evolution is inherently noisy because of random mutations and stochasticity induced by sampling in finite populations. Since the sampling noise is inversely proportional to population size, one expects deterministic dynamics to emerge in large populations, but in practice this regime is hardly every attainable and fluctuations dominate the behavior even in the largest microbial populations. In this talk I will show how the interplay of the stochastic population dynamics with the structure of the underlying fitness landscape can lead to counter-intuitive phenomena such as an adaptive advantage of small populations and a non-monotonic dependence of evolutionary predictability on population size. If time permits, the adaptive benefits of recombination in rugged fitness landscapes will be briefly addressed as well. The talk is based on joint work with Kavita Jain, Johannes Neidhart, Stefan Nowak, Su-Chan Park, Ivan Szendro and Arjan de Visser.

15 min break

Invited Talk SYGP 1.4 Thu 16:45 HSZ 02
Modeling cancer as a stochastic process — •Tibor Antal — School of Mathematics at Edinburgh University, Edinburgh, UK

Stochasticity is essential when modeling initiation of tumors, progression of tumors from benign to malignant states, or metastasis formation. Many aspects of these phenomena can be modeled by simple multi-type branching processes, and the results compare fairly well with experimental and clinical data. These models then can be used to optimize drug treatments. Spatial heterogeneity of tumors are also important for treatment, and their exploration has recently begun by modeling the interplay between tumor shapes and genetic mutations.

Invited Talk SYGP 1.5 Thu 17:15 HSZ 02
Von Neumann's growth model: from statistical mechanics to cell metabolism — •Andrea De Martino — Sapienza Universita' di Roma & CNR, Roma, Italy

This talk reviews the basic properties of Von Neumann's model of growth in production economies, mainly from a statistical mechanics perspective. In addition, I will discuss its recent applications in quantitative biology, for the profiling of a cell's metabolic activity and of its thermodynamics. Finally, a class of Boolean constraint-satisfaction problems based on Von Neumann's idea will be presented, whose solutions allow to shed new light on the modular organization of metabolic networks.