Stefan Karpitschka

Collective Behavior of Motile Microbes

Many bacteria live attached to surfaces, forming dense layers of thousands of cells. Motility coupled to responsive behavior is essential for these organisms to seek and establish appropriate habitats. Although responses like chemo-, mechano-, or phototaxis of individual cells are well studied, much less is known about collective responses that emerge in ensembles of interacting, responsive microorganisms. In this lecture I will present an overview of recent experimental studies on ensembles of motile, surface-attached bacteria, focusing on elongated and filamentous species, and how the statistical physics of active matter predicts the emergent alignment and topology.

Lilach Avitan

The influence of others on self-directed decision making: insights into behavioral and neural mechanisms

The decision-making process of the self is profoundly influenced by the presence or the actions of others. However, the behavioral principles and the underlying neural basis mediating this process are largely unknown. Using the larval zebrafish I will first uncover the manifold of their natural behavioral repertoire. Then I will demonstrate two distinct behaviors affected by others, uncover the underlying behavioral algorithms, and open a window into their underlying neural mechanisms.

Zachary Kilpatrick

Drift-diffusion equations as fundamental models of evidence accumulation and decision making

Organisms continually sample information about their environments, which they use to make decisions. A natural way to mathematically represent these accumulative processes punctuated by actions is to use Drift Diffusion Models (DDMs), stochastic differential equations that can describe the evidence strength, randomness, bias, and choice criteria associated with decisions. In this series of lectures, we will begin by motivating these models as a natural way of mathematically describing the continuous and sequential nature of evidence accumulation and decision making. We will then teach some basic techniques in probability, statistics, and stochastic processes that will allow us to understand why these models are not just a good way but an optimal way of deciding. To do so, we will introduce the concept of reward rate functions, which have their origins in the theory of foraging, but are also extremely useful for understanding animal behavior in controlled laboratory experiments. Extensions we discuss will include mathematical models of decision making in social groups and especially framing foraging in patchy and continuous environments as a sequence of decisions naturally modeled by DDMs.

Serena Ding

Collective behaviour of nematodes

C. elegans has recently emerged as a model for several striking collective behaviours such as aggregation, wurmuration, towering, and network formation. Combining the powerful experimental accessibility of this major lab organism with the knowledge that collective phenomena are widespread and highly relevant for many nematodes, we exploit different nematode species to understand how and why they behave collectively. Through several thematically related projects that I will introduce, we seek to dissect the proximate mechanisms of nematode collective behaviour using tools from quantitative behaviour and modelling, as well as integrating fitness measurements to demonstrate the function of collective behaviour in ecologically relevant groups. I will primarily focus on the aggregation behaviour in the first lecture and the towering behaviour in the second lecture.

Patrick Mueller:

Analysis of multicellular patterns during vertebrate development

A central problem in developmental biology is to understand how tissues are patterned in time and space - how do identical cells differentiate to form the adult body plan? We study how molecules and cells self-organize to produce patterns and collective behavior necessary for normal development. This process involves signaling molecules that orchestrate patterning and dynamic cellular interactions that guide tissue morphogenesis. I will present our recent experimental and theoretical analyses of how biophysical properties such as signal diffusion and stability contribute to axis formation and tissue allocation during vertebrate embryogenesis.

Engineering synthetic self-organizing patterning systems

In addition to analyzing how the interplay between signaling systems leads to patterning during vertebrate development, we are testing our understanding of the principles of multicellular self-organization by developing artificial patterning systems. These synthetic systems are an important proof-of-concept to show how gene regulatory networks can create order from initially random states and may find useful applications in tissue engineering for regenerative medicine. I will present a novel bacterial patterning model based on synthetic genetic circuits and quorum-sensing signals that can serve as a controlled platform for studying collective behavior.

Allyson Sgro

Collective behaviors at the microscale: multicellular coordination

Like animals in the visible world around us, cells in the microscopic world also engage in collective behaviors. Groups of cells of all kinds work together as part of multicellular behaviors ranging from collective migration to developmental synchronization. This lecture will cover both the breadth of behaviors cells can engage in and the depth of understanding that is accessible to us with current tools to probe cellular information processing and behavior. In the initial survey lecture, we will cover examples of multicellular collective behaviors across multiple kingdoms of life, highlighting different ways cells appear to coordinate behaviors and how the natural environment of cells is critical for shaping these behaviors. The follow-up lecture will dive into depth examining the collective behaviors of a single organism, the cellular slime mold *Dictyostelium discoideum*, and how decades of experimental and theoretical research have illuminated the different mechanisms this organism can use to coordinate different processes in different environments for successful survival in stressful conditions. Students will leave with an appreciation for the similarities and differences in the mechanisms and behaviors different organisms at different size scales use to coordinate, as well as a general understanding of what the open questions are in collective behavior at the cellular scale

Ariana Strandburg – Peshkin

Communication and collective behavior in animal societies

Sociality is widespread in nature, but group living requires coordination. From achieving consensus about where to move, to banding together against common enemies, coordinated action requires communication to solve a range of tasks. In many cases, animals rely on sound to communicate, and many species have evolved sophisticated vocal communication systems that facilitate coordination. This talk will explore the interplay between vocal communication and collective behavior. I will present research where we are using multi-sensor collars to track the movements, vocalizations, and behaviors of entire social groups simultaneously as they communicate and coordinate in their natural environment. We focus specifically on three species of social mammals spanning a range of dispersion patterns: highly cohesive meerkats (*Suricata suricatta*), moderately-cohesive white-nosed coatis (*Nasua narica*), and widely dispersed spotted hyenas (*Crocuta crocuta*). Using these data, and through development of machine learning approaches allowing us to detect and classify animal vocalizations and behaviors, we are addressing several questions at the interface of communication and collective behavior. (1) Who has influence over group movement decisions and what is the role of communication in governing these decisions? (2) How does acoustic information flow through groups to mediate collective responses to threats? (3) When and why do groups split up and come back together, and what role does vocal communication play in mediating these fission-fusion dynamics? Ultimately, our goal is to search for common principles that may underlie communication and coordination dynamics across species, while also understanding how social and ecological constraints drive variation in the ways animals communicate and coordinate.

Karoline Wiesner:

Complex system approach to collective behavior

In these lectures I will give an overview of some of the mathematical and computational tools that are used in complexity science research. These include Complex networks, Information theory, and extreme value statistics. I will illustrate then with examples from the research literature. Examples will be drawn from the natural and the social sciences. I will ground the presentation in philosophical foundations of complexity / complexity science.

Daniel Yasumasa Takakshi

Stochastic dynamical systems model of vocal turn-taking and its development in marmoset monkeys

The system of taking turns during vocal exchanges is fundamental to the communication of several animal species, yet their developmental origins and neural mechanisms remain elusive. Marmoset monkeys readily exchange vocalization when in acoustic contact with conspecifics. Moreover, their turn-taking capacity improves during development, decreasing the amount of overlap. We, therefore, used marmosets to explore the neural and developmental basis of turn-taking. To do that, we developed a stochastic dynamical systems model of marmoset monkeys based on the interactions among three neural structures ('drive,' 'motor,' and 'auditory') with feedback connectivity inspired by published physiological and anatomical data. The distinctive feature of our model is that it allows us to measure the amount of noise in the (cognitive) drive separately from the noise in the (sensory) auditory system, where the noise plays a key role as a source of variability in the system. We fitted the stochastic model for each developmental period using vocal production recordings of infant marmosets. We found that during development, the noise level in the auditory sensory system decreases, becoming noiseless after one-month postnatal day. This noiseless period matches the timing of the significant improvement in marmoset capacity to avoid overlapping calls, suggesting that the increased signal-to-noise ratio in the auditory sensory system, but not in the cognitive drive, is a major source for early development of turn-taking capacity.

Einat Couzin-Fuchs

Social plasticity and emergence of collective behavior in swarm forming locusts

Desert locust plagues threaten the food security of millions. Central to their formation is crowding-induced plasticity, with social phenotypes changing from cryptic (solitarious) to swarming (gregarious). The ability to adapt to a changing social environment is a fundamental aspect of life. Locusts exhibit a distinct ability to switch between a solitary and gregarious lifestyle rapidly, rendering them an ideal model for studying social plasticity and the emergence of collective behavior. The change is marked by a wide-range of behavioral, physiological and morphological adaptations including an increased tendancy for aggregartions, synchronised behavior and marching. In this presentation, I will discuss our work on the behaviural, sensory and neural basis of these adaptations leading to gregarious locust behavior. Utilising VR tools to create in the lab virtual swarms of predesigned geometry we show that visual motion cues from conspecifics are sufficient to drive collective motion in gregarious locusts. In the context of foraging, the integration of both visual and olfactory cues is necessary. Calcium imaging from the primary olfactory center (the antennal lobe) provides further clues into the mechanisms by which this is achieved. While the neural representation of social odors is similar in gregarious and solitarious locusts, the evaluation of food-related components in the presence of social odors is significantly enhanced in gregarious animals. Such plasticitry in olfactory processing can therefore facilitate detection of sparse food sources in crowded swarms.

Yitzchak Ben-Mocha

Co-BreeD: advancing comparative research on cooperative breeding with a Cooperative-Breeding Database

Understanding the causes and consequences of cooperative breeding is the focus of an increasing number of comparative meta-analyses. Nevertheless, recent studies demonstrate that datasets on vertebrates include systematic methodological biases, resulting in a growing number of scholars calling for more rigorous curating work. In this talk, we will present the Cooperative Breeding Database (Co-BreeD), which covers key biological parameters of cooperative breeding birds, mammals and humans. We discuss Co-BreeD’s unique curating principles and how being a population-level, peer-reviewed and updatable database enables (i) studying intra- and inter-species variation and linking between fine-scale social and climatic parameters, (ii) accuracy and (iii) expansion with the publication of new data. We will demonstrate Co-BreeD’s potential by presenting the first results showing that female cooperation is more prevalent than commonly thought and how Co-BreeD data contradicts previous studies that are based on biased data.

Fumihiro Kano

What are birds looking at? Fine-scale tracking of birds reveals their use of attention and cognition during free social interactions.

I will overview my lab's recent work using cutting-edge imaging systems, including motion-capture systems and computer vision, to reveal the use of attention in a bird flock under naturalistic contexts. Using a motion-capture system, we have developed a marker-based system to track the head orientation of pigeons and proxy their gaze (where they are looking). More recently, using computer vision, we have shown that similar analysis can be achieved without any attachment of markers, thereby opening new possibilities for fine-scale tracking both in captivity and in the wild, across various species (corvids, great tits), and across various behavioral contexts (vigilance, synchronization, social learning). From the fine-scale tracking data, we revealed how birds achieve collective vigilance in an experiment presenting a model predator to a flock foraging as a group. Moreover, we discovered that birds transmit specific information about the predator in this context, possibly through following the gaze of other flock members.

Laurie Vandevelde

What animals do we make? Ethnographing laboratories and ethological practices

Anthropology of nature, a rapidly expanding disciplinary field, challenges the "great divide" between the West and the rest of the world (Descola, 2005) : since the 1980s, ethnographies of laboratories have described scientific research as a set of locally situated practices, capable of being studied in the same way as others (Latour & Woolgar, 1979 ; Wieder, 1980 ; Candea, 2013). In particular, a comparative approach reveals that laboratory works are not neutral or descriptive, but are rather deeply influenced by the local scientific culture, the sociological background of researchers and the way experiences are constructed (Kreutzer, 2014 ; Despret 2019). Extending the social space to human-animal interactions also allows to consider the affects, emotions and perceptions involved in the relationships with animals, but often hidden or neglected in scientific publications (Despret 2013 ; Wieder, 1980) Relativizing the boundary between nature and culture means, among other things, acknowledging that science is part of a wider socio-cultural, political and economical context, and taking a close look at the methods, beliefs and tools that forge our vision of the animal. It also implies questioning the factors that influence the construction of a legitimate research object and the formulation of results that are publishable and acceptable to the scientific community. To this end, it is useful to encourage dialogue between the social sciences and the natural sciences: this workshop aims to create a space for sharing and reflecting on the biases and constraints that influence our understanding of the "facts" we study. By taking advantage of the plurality of scientific cultures represented, the aim is to create an opportunity for ethologists to carry out an "self-ethnography", in order to reflect together on the multiple animal figures that science fabricates, and to highlight their convergences and divergences.

Janina Wellmann :

The Motion Conundrum: Visualization, Computation, and Mathematics in the Sciences of Moving Life.

Mathilde Delacoux

Motion-Capture: using 3D data to study behavior

Motion-capture is a cutting-edge tracking system that records with very high precision fine-scale movements in a 3D space. It is a technology that opens up a lot of new opportunities to study animal and human behavior. However, working with 3D motion-capture raw data to extract meaningful information can be quite challenging and refrain scientists from using it. With this tutorial, I will introduce this technology, what it is and how it works. But I also want to put focus on concrete application examples to help understanding what researchers can expect from it and the kind of questions that can be answered with it.

Bernadette Denk

"Have you ever walked next to someone and noticed your steps aligning? Have you ever caught “second-hand” stress? When humans interact, they influence each other – down to the physiological level. We can see evidence for this in other species as well, and even between species, like humans and therapy horses. This tutorial is all about synchrony, the correspondence of (physiological) signals between individuals. Focusing on heart rate synchrony, we will design a brief experiment to measure synchrony, learn about different methods to quantify synchrony, and apply these methods to our own data. We will look into time-frequency-based, correlation-based and nonlinear methods, and discuss their assumptions and applications.