

## Abstracts of Invited Talks

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**Vijay Balasubramanian**

University of Pennsylvania

**“Becoming what you smell: adaptive sensing and efficient coding in the olfactory system”**

I propose that the circuit architecture of the early olfactory system provides an adaptive, efficient mechanism for compressing the vast space of odor mixtures into the responses of a small number of sensors. The olfactory sensory repertoire first leverages the power of random matrices to implement a compressive sensing procedure. It then adapts the resulting representation to efficiently encode and optimize information transfer from the changing environment of volatile molecules.

Concerning the program, could you schedule me to speak on the Sunday? I am supposed to fly to China early the next week.

**Carl M. Bender**

Washington University in St. Louis

**"PT symmetry in quantum mechanics and quantum field theory"**

PT-symmetric quantum theory began with an analysis of the strange-looking non-Hermitian Hamiltonian  $H = p^2 + x^2(ix)^\epsilon$ . This Hamiltonian is PT symmetric and the eigenvalues of this Hamiltonian are discrete, real, and positive when  $\epsilon \geq 0$ . In this talk we discuss the corresponding quantum-field-theoretic Hamiltonian  $H = \frac{1}{2}(\nabla\phi)^2 + \frac{1}{2}\phi^2(i\phi)^\epsilon$  in  $D$ -dimensional spacetime, where  $\phi$  is a pseudoscalar field. We show how to calculate the Green's functions as series in powers of  $\epsilon$  directly from the Euclidean partition function. We derive exact finite expressions for the vacuum energy density, the renormalized mass, and the connected  $n$ -point Green's functions for all  $n$  and for  $0 \leq D < 2$ . For  $D \geq 2$  the one-point Green's function and the renormalized mass become infinite, but perturbative renormalization can be performed. The beautiful spectral properties of PT-symmetric quantum mechanics appear to persist in PT-symmetric quantum field theory.

**Bill Bialek**

Princeton University and The CUNY Graduate Center

**“RG-inspired approaches to networks of real neurons”**

The renormalization group teaches us that we can describe macroscopic phenomena with models that are simpler and more universal than the underlying microscopic mechanisms. Can we construct similar paths to simplification in biological systems? After summarizing some of the obvious reasons for pessimism, I will describe efforts that my colleagues and I have made to systematically coarse-grain the patterns of activity that are observed, experimentally, in a real network of neurons (the mouse hippocampus). We find that distributions of coarse-grained variables approach a fixed, non-Gaussian form as the coarse-graining scale is increased, and along this trajectory we see scaling of both static and dynamic quantities. Scaling is precise across two decades, and exponents are reproducible, sometimes to the second decimal place. All of this suggests that the dynamics of these networks are described by a non-trivial fixed point.

**Tommaso Biancalani**

Broad Institute of MIT and Harvard

**“Disentangling bacterial invasiveness from lethality in an experimental host-pathogen system”**

Understanding virulence remains a central problem in human health, pest control, disease ecology and evolutionary biology. Bacterial virulence is typically quantified by phenomenological indicators such as the LT50 (i.e. the time taken to kill 50% of an infected population). However, virulence emerges as a result of complex processes that occur at different stages: the pathogen needs to breach the primary host defenses, find a suitable environment to replicate, and finally express the virulence factors that cause lethality. It is well-known that pathogens exhibit a very broad spectrum of strategies to accomplish these three tasks, yet, phenomenological indicators such as the LT50 cannot distinguish the ability of the pathogen to invade the host from its ability to kill the host. Here, we propose a physical host-pathogen theory that shows how to

disentangle colonization, growth, and pathogen lethality from the survival kinetics of a host population. Preliminary experimental data from *C. elegans* nematodes exposed to various pathogens shows that host mortality becomes severe only once the pathogen population has reached its carrying capacity within the host. In the talk, I will discuss various model predictions and compare them against experimental data.

**Stefan Boettcher**

Emory University, Dept of Physic

**“Complexity bounds on quantum search algorithms in finite-dimensional networks”**

Abstract: We have established [1] a lower bound concerning the computational complexity of Grover’s algorithms on fractal networks. This bound provides general predictions for the quantum advantage gained for searching unstructured lists. It yields a fundamental criterion, derived from quantum transport properties, for the improvement a quantum search algorithm achieves over the corresponding classical search in a network based solely on its spectral dimension,  $d_s$ . Our analysis employs recent advances in the interpretation of the venerable real-space renormalization group (RG) as applied to quantum walks. It clarifies the competition between Grover’s abstract algorithm, i.e., a rotation in Hilbert space, and quantum transport in an actual geometry. The latter is characterized in terms of the quantum walk dimension  $d_w^Q$  and the spatial (fractal) dimension  $d_f$  that is summarized simply by the spectral dimension of the network. The analysis simultaneously determines the optimal time for a quantum measurement and the probability for successfully pinpointing a marked element in the network. The RG further encompasses an optimization scheme devised by Tulsi that allows us to tune this probability to certainty, leaving quantum transport as the only limiting process. It considers entire families of problems to be studied, thereby establishing large universality classes for quantum search, which we verify with extensive simulations. The methods we develop could point the way towards systematic studies of universality classes in computational complexity to enable modification and control of search behavior. [1] Phys. Rev. A 98, 012320 (2018) With Shanshan Li (Emory U), Tharso D. Fernandes (UFES), and Renato Portugal (LNCC)

**Paul Bourgade**

New York University

**“Overlaps between eigenvectors of Ginibre matrices”**

Eigenvectors of non-hermitian matrices are non-orthogonal, and their distance to a unitary basis can be quantified through the matrix of overlaps. These variables quantify the stability of the spectrum, and characterize the joint eigenvalues increments under Dyson-type dynamics. They first appeared in the physics literature; well known work by Chalker and Mehlig calculated the expectation of these overlaps for complex Ginibre matrices. For the same model, we extend their results by deriving the distribution of the overlaps and their correlations. As a corollary, at equilibrium, eigenvalues move with diffusive scaling under the Dyson-dynamics. (Joint work with G. Dubach).

**Christian Brennecke**

Harvard University

**“Bogoliubov Theory in the Gross-Pitaevskii Limit”**

We consider Bose gases consisting of  $N$  particles trapped in a box with volume one and interacting through a repulsive potential with scattering length of the order  $N^{-1}$  (Gross-Pitaevskii regime). We determine the ground state energy and the low-energy excitation spectrum, up to errors vanishing as  $N \rightarrow \infty$ . Our results confirm Bogoliubov’s predictions. This is joint work with C. Boccato, S. Cenatiempo and B. Schlein.

**Edouard Brezin**

Ecole Normale Supérieure

**"Random matrices and geometry of surfaces, an historical survey"**

This is merely an historical account of field theory with large matrices. It started with 't Hooft’s work on gauge theories for  $SU(N)$ , expanded in powers of  $1/N$ . It revealed a correspondence between the genus of a two-

dimensional surface and the  $1/N$  expansion. Following this line random matrices turned out to be very useful in numerous enumeration problems, and also to compute the partition function of random triangulated surfaces, i.e. two-dimensional gravity. After Witten and Kontsevich, the use of random matrices in topological field theory and related geometric problems, became ubiquitous.

**David Campbell**

Boston University

**“The Subtle Road to Equilibrium in the FPUT Model”**

The interpretation and consequences of the celebrated Fermi, Pasta, Ulam, Tsingou (FPUT) numerical experiment have challenged scientists for more than six decades.

The history of how the original FPUT discovery led to the theory of “solitons,” was key in the understanding of Hamiltonian chaos, and led to the birth of “nonlinear science” is well documented, but there are many fascinating details which are only now being explored and understood. In this presentation, I will discuss two recently studied examples: namely, the details of the existence and breakdown of recurrences and super-recurrences in both the alpha- and beta- versions of the FPUT system, and the remarkable intermittent dynamics, involving long-time, large deviations, that occur once the systems has nominally reached equilibrium.

In the first study<sup>1</sup>, we find higher-order recurrences (HoR)s—which amount to “super-super-recurrences” in both the alpha and beta models. The periods of these HoR scale non-trivially with energy due to apparent singularities caused by nonlinear resonances, which differ in the two models. Further, the mechanisms by which the HoR breakdown differ strikingly in the two models.

In the second study<sup>2</sup>, we find that the dynamics at equilibrium is characterized by a power-law distribution of excursion times far off equilibrium, with diverging variance. Long excursions arise from sticky dynamics close to localized excitations in normal mode space (q-breathers). Measuring the exponent allows to predict the transition into nonergodic dynamics.

\*Work in collaboration with Carlo Danielli, Sergej Flach, and Salvatore Pace,

1 Salvatore D. Pace and David K. Campbell, “Behavior and Breakdown of Higher-Order-Fermi-Pasta-Ulam-Tsingou Recurrences,” arXiv:1811.00663 (Chaos, to appear)

2 C. Danielli, D. K. Campbell, and S. Flach, “Intermittent many-body dynamics at equilibrium,” Phys. Rev. E 95 060202(R) (2017).

**Eric Carlen**

Rutgers University

**“Spectral Gaps for Reversible Markov Processes with Chaotic Invariant Measures: The Kac Process with Hard Sphere Collisions in Three Dimensions”**

We develop a method for producing estimates on the spectral gaps of reversible Markov jump processes with chaotic invariant measures, that is effective in the case of degenerate jump rates, and we apply it to prove the Kac conjecture for hard sphere collision in three dimensions.

**Arup Chackraborty**

MIT

**“Inducing cross-reactive antibody responses by vaccination: a crossroad of statistical mechanics”**

Vaccination has saved more lives than any other medical procedure. But, today some pathogens have evolved that defy successful vaccination using the empirical paradigms pioneered by Pasteur and Jenner over two centuries ago. HIV is a prominent example. A major barrier to the development of a vaccine against HIV is the high mutability of the virus, which enables HIV to mutate to evade vaccine-induced antibodies and T cells that lie ready and waiting for certain strains. Antibodies are produced by a non-equilibrium Darwinian evolutionary process called affinity maturation. A question of great interest is how vaccination protocols can be designed to elicit antibodies that are cross-reactive to diverse HIV strains. I will describe work that shows how vaccination

with multiple variant strains to induce cross-reactive antibodies results in conflicting selection forces that “frustrate” affinity maturation. I will then discuss how optimal temporal patterns of frustration can promote the evolution of broadly neutralizing antibodies.

**Eugene M. Chudnovsky**  
“Human rights of scientists”

Lehman College

**Rodica Costin**  
“Nonperturbative time dependent solution of a simple ionization model”

Ohio State University

We obtain the non-perturbative solution of the Schrödinger equation with a time-dependent potential (a delta function multiplying  $(2+r \sin(\omega t))$ ) modeling the ionization of a model atom by a parametric oscillating potential. This model has been studied extensively by many authors. It has surprisingly many features in common with those observed in the ionization of real atoms and emission by solids subjected to microwave or laser radiations suggesting a form of universality in different emission processes.

We use new mathematical methods to provide a complete and rigorous analysis of this system. We obtain the Borel-resummed transseries (multi-instanton expansion) valid for all values of  $r, \omega, t$  for the wave function, ionization probability, and energy distribution of the emitted electrons. We show that for large  $t$  and small  $r$  the energy distribution has sharp peaks at energies which are multiples of  $\omega$ , corresponding to photon capture. We obtain small  $r$  expansions that converge for all time, unlike those of standard perturbation theory.

Joint work with Ovidiu Costin and Joel Lebowitz.

**Ayşe Erzan**  
“Field theory and renormalization group on non-metric spaces”

Istanbul Technical University

We implement the analogue of the “momentum space” renormalization group à la Wilson for a scalar  $\psi^4$  field theory on deterministic networks, which are not translationally invariant and not necessarily embedded in metric spaces. For these non-metric spaces the correlation length is not well defined and hyperscaling relations cannot be used. Our method relies on a generalized Fourier analysis using the eigenvectors of the graph Laplacian, which may be explicitly calculated using the symmetries of the networks. On the hierarchical lattice, the critical exponents depend on the spectral dimension  $d_s$ , which can be varied using Itzykson's scheme. At the lower critical dimension for the Ising universality class, up to second order the Gaussian fixed point is stable with respect to quartic perturbations, as previously observed by Wilson. Non-Gaussian fixed points arise for  $2 < d_s < 4$ .

A. Tuncer and A. Erzan, “Spectral renormalization group for the Gaussian model and  $\psi^4$  theory on non-spatial networks,” Phys. Rev. E 92, 022106 (2015).

A. Erzan and A. Tuncer, “Explicit construction of the eigenvectors and eigenvalues of the graph Laplacian on the Cayley tree,” <https://arxiv.org/pdf/1806.01006>

**Paul Goldbart**  
“Nature's simplest amorphous solids”

University of Texas at Austin

Amorphous solids continue to present fascinating challenges, both conceptual and technical. Their simplest realization is found when enough permanent bonds are introduced, at random, between the constituents of a fluid of macromolecules to induce amorphous solidification. I shall discuss where this simplicity comes from, how such systems may be modeled and analyzed, and what challenges remain. By carefully delineating between the concepts of localization, percolation and rigidity, we shall see that -- provided certain twists are added -- a familiar kind of statistical field theory enables access to certain core universal characteristics of this simplest class of amorphous solids.

**Björn Hof**

IST Austria

**“The universality class of the transition to turbulence”**

The transition to turbulence in simple shear flows (e.g. pipe, channel and Couette flow) has remained an open problem for over a century. Typically here turbulence arises despite the linear stability of the laminar flow and results from perturbations of finite amplitude. Turbulence at first appears in the form of localised patches (e.g. puffs, spots or stripes) which coexist with laminar flow, resulting in complicated, disordered flow patterns (spatio-temporal intermittency). Individual turbulent domains can collapse or they can proliferate and seed other patches of turbulence. The time scales on which flows evolve are extremely large and likewise are the relevant length scales. Characterizing the transition process hence requires experiments of very large aspect ratios and extremely long observation times. In detailed experiments and direct numerical simulations of Couette flow we could for the first time determine the critical exponents that characterize this transition and show that it falls into the directed percolation universality class.

**Ian Jauslin**

Princeton University

**“Solution of the time dependent Schrödinger equation for photoemission from a metal surface”**

One of the tried and true techniques to ionize electrons from a metal is to shine an intense laser pulse on the metal's surface. In this talk I will discuss a simple model for this process, in which the laser is a classical, time-dependent oscillating field. The electron wavefunction is initially taken to be in a steady state of the system without a field, and, at  $t=0$ , the laser is switched on. I will discuss how the system evolves to a periodic regime in which the electrons are in resonance with the exciting field.

**Mehran Kardar**

MIT

**“Bacterial range expansions on a growing front: Roughness, Fixation, and Directed Percolation”**

Directed Percolation (DP) is a classic model for nonequilibrium phase transitions into a single absorbing state (fixation). It has been extensively studied by analytical and numerical techniques in diverse contexts. Recently, DP has appeared as a generic model for the evolutionary/ecological dynamics of competing bacterial populations. Range expansion - the stochastic reproduction of bacteria competing for space to be occupied by their progeny - leads to a fluctuating and rough growth front, which is known from experiment and simulation to affect the underlying critical behavior of the DP transition. We employ symmetry arguments to construct a pair of non-linear stochastic partial differential equations describing the co-evolution of surface roughness with the composition field of DP. Macroscopic manifestations (phenomenology) of these equations on growth patterns and genealogical tracks of range expansion will be presented. Jordan M. Horowitz, Mehran Kardar

**Igor Klebanov**

Princeton University

**“Large N Tensor Models”**

We review the combinatorics of models where the degrees of freedom are tensors of rank three. For specially chosen interactions, the Feynman graph expansion is dominated by the so-called melonic graphs in the large  $N$  limit. We present the simplest tensor quantum mechanical model for Majorana fermions, which has  $O(N)^3$  symmetry, and compare it with the Sachdev-Ye-Kitaev model. When two tensor or SYK models are coupled by a quartic interaction, a gap can appear in the spectrum indicating spontaneous breaking of a  $Z_2$  symmetry.

**Christian Maes**

KU Leuven

**“Cosmic acceleration from quantum Friedmann equations”**

We consider a simplified model of quantum gravity using a mini-superspace description of an isotropic and homogeneous universe with dust. We derive the corresponding Friedmann equations for the scale factor, which now contain a dependence on the wave function. We identify wave functions for which the quantum effects lead to a period of accelerated expansion that is in agreement with the apparent evolution of our universe, without introducing a cosmological constant. Authors: Thibaut Demaerel, Christian Maes and Ward Struyve (Instituut voor Theoretische Fysica, KU Leuven)

**Juan Maldacena**

Institute for Advanced Study

**"Entanglement and the geometry of spacetime"**

We will discuss how the quantum mechanical property of entanglement is related to the geometry of spacetime.

**Vieri Mastropietro**

University of Milan

**"Renormalization Group and Anomalies in interacting Lattice Weyl semimetals"**

Weyl semimetals are materials with an emerging description in terms of massless  $3+1$  Dirac fermions.

Phenomena related to the presence of the chiral anomaly have been observed by several groups.

We theoretically investigate the universality properties of the analogue of the anomaly in interacting lattice

Weyl semimetals, by using rigorous Renormalization Group methods and Ward Identities.

**Narayanan Bhargav Peruvemba**

Rutgers University

**"Diffusion on graphs"**

Diffusion on a graph is a cellular automaton describing how integer labels on the vertices evolve. The label of a vertex is just the number of particles at that vertex, and at each step, each vertex simultaneously sends one particle to each of its neighbours with fewer particles, mimicking flow towards lower concentrations.

What can we say about the trajectories of various initial configurations in this process? Here's an amuse bouche: this firing rule may generate negative labels when started from a completely positive initial configuration, so it is not clear, a priori, if one must even have a stable final state, or even periodic behavior necessarily!

**Phil Nelson**

University of Pennsylvania

**"The Role of Quantum Decoherence in Fluorescence Resonance Energy Transfer"**

Resonance energy transfer has become an indispensable experimental tool for single-molecule and single-cell biophysics. Its physical underpinnings, however, are subtle: it involves a discrete jump of excitation from one molecule to another, and so we regard it as a strongly quantum-mechanical process. And yet its kinetics differ from what many of us were taught about two-state quantum systems, quantum superpositions of the states do not seem to arise, and so on. Although J. R. Oppenheimer and T. Förster navigated these subtleties successfully, it remains hard to find an elementary derivation in modern language. The key step involves ideas I first learned from Curt Callan. [Nelson, P. C. (2018). Biophysical Journal, 115(2), 167–172.

**Stefano Olla**

Universite` Paris Dauphine-PSL

**"Fick's law with phase transitions"**

We characterize the non equilibrium stationary states in two classes of systems where phase transitions are present. We prove that the interface in the limit is a plane which separates the two phases and we study its fluctuations. Work in collaboration with Anna De Masi and Errico Presutti.

**Jeremy Quastel**

University of Toronto

**"The strong coupling fixed point of the KPZ universality class"**

We describe the scaling invariant, completely integrable Markov process which governs long time large scale fluctuations of 1d random interface growth. It was discovered through a complete solution of TASEP, the most popular discretization of the Kardar-Parisi-Zhang equation. Joint work with Konstantin Matetski and Daniel Remenik

**Pablo Sartori**

Institute for Advanced Study



**“What thermal physics can teach us about protein complexes”**

Biological functions are established through evolution, but are constrained by the laws of physics. Protein complexes, macromolecular assemblies evolved to carry out most cellular functions, are an example of this. We argue that thermal physics constrains how reliably these structures can self-assemble. We study a minimal equilibrium model of protein complexes, and show that the constraint of reliable self-assembly requires that complexes satisfy two conditions: (i) the composition of the complexes needs to be heterogeneous, and (ii) the use of the proteome by the complexes has to be sparse. Our analysis of publicly available datasets indicates that cellular systems might have indeed evolved so to satisfy both of these conditions.

**Tatyana Shcherbina**

Princeton University

**“Universality for random band matrices”**

Random band matrices (RBM) are natural intermediate models to study eigenvalue statistics and quantum propagation in disordered systems, since they interpolate between mean-field type Wigner matrices and random Schrodinger operators. In particular, RBM can be used to model the Anderson metal-insulator phase transition (crossover) even in 1d. In this talk we will discuss some recent progress in application of the supersymmetric method (SUSY) and transfer matrix approach to the analysis of local spectral characteristics of some specific types of 1d RBM.

**Hong-Yan Shin**

University of Illinois

**“How is turbulence born: Spatiotemporal complexity and directed percolation in driven fluids”**

How a laminar flow becomes turbulent has been an unsolved problem for 130 years, ever since Osborne Reynolds noticed that turbulence arises in a non-uniform manner in space. A decade ago, precise measurements in pipe flow experiments quantified this non-trivial spatiotemporal complexity, showing that turbulence arises through localized "puffs" that decay and split in a complex way, but whose mean lifetime and splitting time grow faster than exponentially with the control parameter as the transition is approached. From numerical simulations of the Navier-Stokes equations, we identified the important long-wavelength modes at the transition, and discovered the surprising fact that these modes interact with the small-scale turbulence through an emergent stochastic predator-prey dynamics. Solving the statistical mechanics of this effective Landau theory, we could replicate the spatiotemporal complexity, and make the prediction that the turbulence emerges through a sharp non-equilibrium phase transition in the directed percolation universality class. Experimental measurements of the critical exponents and universal scaling functions confirm this prediction in a variety of flow geometries, while finite-size scaling accounts for the faster than exponential lifetime behavior. Our work provides a unified picture of the transition to turbulence emerging in systems ranging from turbulent convection to magnetohydrodynamics.

**Nicolas Sourlas**

École Normale Supérieure

**“Fermionic Duality”**

Duality transformations play a very important role in theoretical physics. In this talk I propose new duality transformations for fermionic theories. They map the strong coupling regime of one theory to the weak coupling regime of another theory. These transformations are based on the functional integral representation of the fermionic theories in terms of Grassmann variables and rely heavily on the properties of Grassmann variables. Potential applications include the study of the strong coupling phase of the two dimensional Hubbard model.

**Katepalli Sreenivasan**

New York University

**“Around loops in hydrodynamic turbulence”**

This talk will be a report on our recent work on circulation in hydrodynamic turbulence and its implications for anomalous scaling.

**Ramon Van Handel**

Princeton University

**“Quantum graphs and convex geometry”**

Quantum graphs---that is, Laplacians on metric graphs with Kirchoff boundary conditions---have been used in mathematical physics to model a range of phenomena, from wave guides and photonic crystals to quantum chaos and localization. In this talk, I will aim to explain how we recently encountered these objects unexpectedly in a very different area of mathematics, namely convex geometry. Exploiting the structure of these models yields a key part of the solution of a 120 year old problem of H. Minkowski. (This is joint work with Yair Shenfeld.)

**Kalin Vetsigian**

University of Wisconsin (Madison)

**“Emergent eco-evolutionary phenomena in microbial communities”**

The complexity of microbial community dynamics stems not only from the diversity of these communities and the richness of their microbial interactions but also from the fact that many of these interactions can readily evolve. As mutant strains with altered interactions increase in frequency they reshape the ecological dynamics and the selection pressures on existing strains. The spectrum of possible consequences of such an interplay between ecology and evolution are poorly understood. To start filling this gap, we investigated the eco-evolutionary dynamics in communities dominated by toxin-mediated interactions. Such interactions are ubiquitous among soil microbes, and whether and how they contribute to diversity has been a long-standing puzzle. We identified several emergent eco-evolutionary phenomena. First, the dynamics could robustly discover complex evolutionary stable states in which multiple strains coexist (Nash equilibria) despite the fact that such states are unreachable through a step-by-step community assembly. Rather, the system as a whole tunnels between collective states via a fundamentally eco-evolutionary process. Second, communities of particular strains can emerge and persist even if these communities are not ecologically stable. Finally, the dynamics can exhibit intermittency in which prolonged periods of apparent community stability are interrupted by periods of fast strain turnover. In spatially structured communities, this intermittency leads to mosaics in which different spatial regions are in different eco-evolutionary regimes in a phenomenon reminiscent of phase coexistence in material science. These findings demonstrate that toxin-mediated interactions are a viable mechanism for explaining diversity, provide a qualitatively new mechanism for adaptive diversification, and expand our understanding of the different possible modes of eco-evolutionary dynamics in microbial communities.

**Vincenzo Vitelli**

University of Chicago

**“Odd Elasticity”**

Hooke's law states that the deformations or strains experienced by an elastic object are proportional to the applied forces or stresses. The number of coefficients of proportionality between stress and strain, i.e. the elastic moduli, is constrained by energy conservation. In this Letter, we generalize continuum elasticity to media in which energy is not conserved, such as solids with microscopic activity. This generalization, which we dub odd elasticity, reveals that two additional elastic moduli exist in an isotropic solid with non-conservative interactions. Such an odd-elastic solid can be regarded as a distributed engine: work is locally extracted, or injected, during quasi-static cycles of deformation. By coarse graining illustrative microscopic models, we show how odd elasticity emerges in active metamaterials composed of non-reciprocal springs that actuate internal torques in response to strain. Our predictions, corroborated by simulations, uncover phenomena ranging from activity-induced auxetic behavior and buckling to wave propagation powered by self-sustained active elastic cycles.

**Aleksandra Walczak**

CNRS and Ecole Normale Supérieure

**“Prediction in immune repertoires”**



Predicting the future state of a complex environment requires weighing the trust in new observations against prior experiences. In this light, I will present a view of the adaptive immune system as a dynamic Bayesian machinery that updates its memory repertoire by balancing evidence from new pathogen encounters against past experience of infection to predict and prepare for future threats. The results suggest that pathogenic environments are sparse and that memory repertoires significantly decrease infection costs even with moderate sampling.

**Shenshen Wang**

University of California, Los Angeles

**“Evolving generalists in changing landscapes”**

Evolving systems, be it an antibody repertoire in the face of mutating pathogens or a microbial population exposed to varied antibiotics, respond to ever changing environments through a constant search for adaptive solutions in high-dimensional fitness landscapes. Generalists are robust performers that remain fit under varied environmental conditions. For better (induction of broad antibody response) or worse (emergence of multi-drug resistance), it is important for evolution to discover these adaptive solutions efficiently. Yet, whether and when environmental changes can offer them evolutionary advantage over specialists remains an open question. We use a generative model within a generic landscape framework to study evolutionary discovery of generalists in slowly changing environments. We show that switching rugged fitness landscapes can enhance the propensity to evolve high performers, if the landscapes' topography is related in a way that balances the trade-offs between diversity, quality and accessibility of such solutions, thus demonstrating a general route toward favoring or avoiding generalists via a proper choice of cycling environments.