Abstracts of Invited Talks

William Bialek - Princeton University
Recent progress on statistical physics for networks of real neurons
Neural networks have been a source of statistical physics problems for generations. New experiments provide new opportunities to connect these ideas with data on real brains. I'll describe recent progress in providing very precise descriptions of patterns of activity in ~100 neurons, approximate descriptions of 1000+ neurons, and exploring how the arrow of time is represented in neural dynamics.

Arup Chakraborty – MIT
Statistical Mechanics of Antibody Production Upon Vaccination
Infectious disease-causing pathogens have plagued humanity since antiquity, and the COVID-19 pandemic has been a vivid reminder of this perpetual existential threat. Vaccination has saved more lives than any other medical procedure, and effective vaccines have helped control the COVID-19 pandemic. However, we do not have effective vaccines against rapidly mutating viruses, such as HIV; nor do we have a universal vaccine against seasonal variants of influenza or new variants of SARS-CoV-2. I will describe how by bringing together approaches from statistical physics, virology and immunology, progress is being made to address this challenge. I will focus on the antibody arm of this challenge. Antibodies are produced by a far from equilibrium stochastic dynamic evolutionary process. I will describe statistical physics-based models of antibody evolution and complementary data from animals and humans that shed light on how this process might be modulated to produce desired antibody responses.

David G. Clark – Columbia University
Mean fields for nice advisors
Neural networks are high-dimensional nonlinear dynamical systems that process information through the coordinated activity of many connected units. Understanding how biological and machine-learning networks function and learn requires knowledge of the structure of this coordinated activity, information contained, for example, in cross covariances between units. Self-consistent dynamical mean field theory (DMFT) has elucidated several features of random neural networks—in particular, that they can generate chaotic activity—however, a calculation of cross covariances using this approach has not been provided. I will describe a recent self-consistent calculation of cross covariances using a two-site cavity DMFT. This theory allows us to probe spatiotemporal features of activity coordination in a classic random-network model with i.i.d. couplings, showing an extensive but fractionally low effective dimension of activity and a long population-level timescale. I will also describe how this theory can capture the effect of structure in the couplings that could arise through learning.

Gavin Crooks – Normal Computing
Thermodynamic Geometry of Matrix Determinants
Linear algebraic primitives are at the core of many modern algorithms in engineering, science, and machine learning. Hence, accelerating these primitives with novel computing hardware would have tremendous economic impact. Such linear algebra problems can be solved by sampling from the thermodynamic equilibrium distribution of a collection of coupled harmonic oscillators. We will present thermodynamic algorithms for computing matrix determinants, and discuss optimal designs using thermodynamic geometry.

Predrag Cvitanovic – Georgia Institute of Technology
A chaotic lattice field theory

We describe spatiotemporally chaotic (or turbulent) field theories discretized over d-dimensional lattices in terms of sums over their multi-periodic orbits.
`Chaos theory' is here recast in the language of statistical mechanics, field theory, and solid state physics, with the traditional periodic orbits theory of low-dimensional, temporally chaotic dynamics a special, one-dimensional case.
In the field-theoretical formulation, there is no time evolution. Instead, treating the temporal and spatial directions on equal footing, one enumerates the spatiotemporal field configurations that contribute to the partition sum of the theory, each a solution of the system's defining deterministic equations, with sums over time-periodic orbits of dynamical systems theory replaced by sums over d-dimensional spacetime geometries, the weight of each orbit given by the Hill determinant of its spatiotemporal orbit Jacobian matrix. A further reformulation of the theory in terms of a spatiotemporal zeta function utilizes the shadowing of large cells by smaller ones, with the predictions of the theory dominated by the shortest periods configurations.

Sebastian Deffner - UMBC (University of Maryland, Baltimore County)
Pointer states and quantum Darwinism with 2-body interactions
Quantum Darwinism explains the emergence of classical objectivity within a quantum universe. However, to date most research in quantum Darwinism has focused on specific models and their stationary properties. To further our understanding of the quantum-to-classical transition it appears desirable to identify the general criteria a Hamiltonian has to fulfill to support classical reality. To this end, we categorize all models with 2-body interactions, and we show that only those with separable interaction of system and environment can support a pointer basis. We further show that "perfect" quantum Darwinism can only emerge if there are no intra- environmental interactions. Our analysis is complemented by the solution of the ensuing dynamics. We find that in systems that exhibit information scrambling, the dynamical emergence of classical objectivity is in direct competition with the non-local spread of quantum correlations. Our rigorous findings are illustrated with the numerical analysis of four representative models.
(Reference: Paul Duruisseau, Akram Touil, and Sebastian Deffner, arXiv:2309.03299)

Edward Farhi – Google / MIT
The Quantum Approximate Optimization Algorithm and the Sherrington-Kirkpatrick model
I will explain how a quantum algorithm can be used to find low energy configurations of the SK model

Martin Fraas – UC Davis
Kitaev's determinant formula
We establish a sufficient condition under which det(ABA^{-1}B^{-1})=1 for a pair of bounded, invertible operators on a Hilbert space. This is a joint work with Alex Elgart.

Jordan Horowitz – University of Michigan
Kinetic response in nonequilibrium steady states
How a system responds to external perturbations informs our understanding of how physical properties are shaped by microscopic characteristics. Near thermodynamic equilibrium, this understanding is organized through the Fluctuation-Dissipation Theorem (FDT): fluctuations and response encode the same information. The FDT's utility has led to significant interest in developing similar predictions valid away from equilibrium. In this talk, I will show that the degree to which the FDT is broken is linked to how the system responds to changes in its kinetic parameters, and provide limits to this response in terms of thermodynamic and structural properties. To illustrate these results, I will draw on examples from biophysics, where the effectiveness of numerous biochemical systems depends on being exquisitely sensitive to changes in chemical inputs.

Ian Jauslin – Rutgers University
Non-perturbative behavior of interacting Bosons at intermediate densities
Much attention has been given to systems of interacting Bosons in the dilute regime, where powerful theoretical tools such as Bogolyubov theory give detailed and accurate predictions. In this talk, I will discuss a

different approach to studying the ground state of Boson systems, which Carlen, Lieb and I have recently found to be accurate at all densities. In particular, it allows us to probe the system in the intermediate density regime, which had, until now, only been accessible to costly Monte-Carlo simulations. In this talk, I will first give an overview of this Simplified approach, and will discuss evidence for non-perturbative behavior in the intermediate density regime obtained using this tool.

Anton Kapustin – Cal Tech

Extracting topological invariants from ground-state wavefunctions.

I will explain how to extract numerical invariants from states of infinite-volume quantum lattice systems which are gapped ground state of U(1)-invariant local Hamiltonians. These invariants are topological in the sense that they do not change if one varies the parameters of the Hamiltonian while keeping the gap nonzero. For two-dimensional systems, this invariant is the zero-temperature Hall conductance. Generalizations to Hamiltonians invariant under an arbitrary compact Lie group G are also possible and produce topological invariants taking values in G-invariant polynomials on the Lie algebra of G.

Eleni Katifori – University of Pennsylvania

A paradox in physical networks of optimal exploration

We utilize transport systems daily to commute, e.g. via road networks, or bring energy to our houses through the power grid. Our body needs transport networks, such as the lymphatic, arterial or venous system, to distribute nutrients and remove waste. If the transported quantity is information, for example carried by an electrical signal, then even the internet and the brain can be thought of as members of this broad class of webs. Despite our daily exposure to transport networks, their function and physics can still surprise us. This is exemplified by the Braess paradox, where the addition of an extra road in a network worsens rather than improves traffic contrary to a naïve prediction.

In this talk, we consider stochastic transport in geometrically embedded graphs. Intuition suggests that providing a shortcut between a pair of nodes improves the time it takes to randomly explore the entire graph. Counterintuitively, we find a Braess' paradox analog. For regular diffusion, shortcuts can worsen the overall search efficiency of the network, although they bridge topologically distant nodes. We propose an optimization scheme under which each edge adapts its conductivity to minimize the graph's search time. The optimization reveals a relationship between the structure and diffusion exponent and a crossover from dense to sparse graphs as the exponent increases.

Alex Kontorovich – Rutgers University

Why teach a computer how mathematicians prove theorems

We'll describe some progress in how and why mathematics is formalized in "interactive proof assistant" software, and potential applications thereof.

Gabriel Kotliar – Rutgers University

Understanding heavy fermions: emergent properties of the Anderson lattice model#

We study paramagnetic quantum criticality in the periodic Anderson model (PAM) using dynamical mean-field theory methods with the numerical renormalization group (NRG) as an impurity solver. The PAM describes an itinerant c band hybridizing with a localized f band. At T=0, it exhibits a hybridization tuned Kondo breakdown quantum critical point (KB-QCP) from a Kondo to an RKKY phase. At the KB-QCP, the f band changes character from itinerant to mainly localized, while the c band remains itinerant. It is a prototypical model describing the essential physics of rare earth and actinide based intermetallic compounds. This simple model is arguably the simplest arena in which to investigate metallic states which depart from the Landau theory of Fermi liquids. We will compare our findings with experimental results in various heavy fermion materials.

Work with Andreas Gleis, Seung-Sup B. Lee, Andreas Weichselbaum and Jan von Delft,

Zhiyue Lu – UNC Chapel Hill
Designing Chemical Reaction Networks for Free Energy Rectification: A Geometric Approachorganisms
Macroscopic machines, such as thermal engines, can harness energy from non-equilibrium environments, such as temperature gradients, to perform work. Historically, their designs have been informed by both universal thermodynamic principles and material-specific considerations. Drawing inspiration from this, the question arises: Can we apply non-equilibrium stochastic thermodynamics to design efficient chemical engines at the nanoscale? In this presentation, I will introduce a geometric theoretical framework that sheds light on cyclic chemical reaction networks, such as catalysis networks, to harness energy from rapid environmental oscillations. Examples of environmental oscillation include oscillation in temperature, pressure, and electric fields. This theory (1) sets a theoretical limit for oscillation-induced performance and (2) offers practical design principles to achieve desired outcomes in oscillation-pumped chemical reaction networks.

David Minh, Illinois Institute of Technology
Targeted free energy perturbation for learned mappings of molecular structure
Targeted free energy perturbation uses an invertible mapping to promote configuration space overlap and the convergence of free energy estimates. However, developing suitable mappings can be challenging. Wirnsberger et al. [J. Chem. Phys. 153, 144112 (2020)] demonstrated the use of machine learning to train deep neural networks that map between Boltzmann distributions for different thermodynamic states. We have adapt their approach to the free energy differences of a flexible bonded molecule, deca-alanine, with harmonic biases and different spring centers. When the neural network is trained until "early stopping"—when the loss value of the test set increases—we calculate accurate free energy differences between thermodynamic states with spring centers separated by 1 Å and sometimes 2 Å. For more distant thermodynamic states, the mapping does not produce structures representative of the target state, and the method does not reproduce reference calculations.

Sefano Olla - Université Paris Dauphine
Speeding up the totally asymmetric exclusion process
We investigate the large deviations for the total current in the TASEP, in particular for the probability to observe a larger flow of particle than the average in the hyperboling space-time scaling. In collaboration with Anastasiia Trofinova (GSSI) and Lu Xu (GSSI).

Garegin Papoian – University of Maryland
Towards Simulating Eukaryotic Cells from the Fundamental Physico-Chemical Principles
Cells of higher organisms contain a dynamically remodeling filamentous network, called cytoskeleton, comprised of actin, myosin and many other molecules. The cytoskeleton endues cells with their instantaneous shapes, providing a machinery for cells to move around, generate forces and also integrate both chemical and mechanical signaling. In terms of the physico-chemical mechanisms, the underlying acto-myosin network growth and remodeling processes are based on a large number of chemical and mechanical interactions, which are mutually coupled, and spatially and temporally resolved. To investigate the fundamental principles behind the self-organization of these networks, we have developed a detailed physico-chemical, stochastic model (MEDYAN, http://medyan.org) of the cytoskeletal dynamics, where the mechanical rigidity of filaments and their corresponding deformations under internally and externally generated forces are taken into account. We have also developed a flexible membrane model that interacts mechanically and chemically with both solution and gel phases, enabling simulations of vesicles containing a chemically active cytoskeleton. I will discuss our recent progress in simulating multi-micron scale

cytosolic/cytoskeletal dynamics at 1000 seconds timescale, and also highlight the outstanding challenges in bringing about the capability for routine molecular modeling of eukaryotic cells.

Pablo Sartori - Gulbenkian Institute of Science
Energetics of metabolism in unicellular organisms
Unicellular organisms possess the remarkable capacity to grow and proliferate in vastly different environments by adapting their metabolism. While the benefits of this metabolic adaptation are self-evident, its costs remain largely unknown. Because growth occurs far from thermodynamic equilibrium, free-energy dissipation has long been hypothesized to pose key constraints to cellular life and its evolution. To investigate this hypothesis, we curated over 450 unicellular growth experiments across evolution and environments and analyzed them using a minimal non-equilibrium thermodynamic framework. We find that despite vast variability in biomass yield and dissipation, the dissipative cost of growth is largely conserved across metabolic types. This conserved cost constraint arises from a fine balance between the large amounts of free energy flowing in and out of cells and is independent of microbial species. Our work places non-equilibrium thermodynamics at the center of cellular growth and proliferation and paves the way for future investigations on the interplay between metabolism, evolution, and non-equilibrium thermodynamics.

Jacob Shapiro – Princeton University
Classification of disordered insulators in 1D
In this talk I will describe some of the mathematical aspects of disordered topological insulators. These are novel materials which insulate in their bulk but (may) conduct along their edge; the quintessential example is that of the integer quantum Hall effect. What characterizes these materials is the existence of a topological index, experimentally measurable and macroscopically quantized. Mathematically this is explained by applying algebraic topology to the space of appropriate quantum mechanical Hamiltonians; I will survey some recent results mainly concentrating on the classification problem in one dimension, where the problem reduces to studying spaces of unitaries (resp. orthogonal projections) which essentially-commute with a fixed projection.

Robert Sims – University of Arizona
Stability of the Bulk Gap for Models with Frustration-Free Ground States
We prove that uniformly small short-range perturbations do not close the bulk gap above the ground state of frustration-free quantum spin systems that satisfy a local topological quantum order condition.
In contrast with earlier results, we do not require a positive lower bound for finite-system Hamiltonians uniform in the system size. To obtain this result, we adapt the Bravyi-Hastings-Michalakis strategy to the GNS representation of the infinite-system ground state. This is joint work with Bruno Nachtergaele (UC Davis) and

Kanu Sinha – Arizona State University
Quantum and classical Brownian motion of a polarizable particle in thermal fields
The noise of the quantized electromagnetic (EM) field engenders a range of fascinating phenomena -- from atomic spontaneous emission to Casimir forces. Similar to a pollen grain in the noisy environment of fluid molecules exhibiting random walk, a polarizable particle interacting with the fluctuations of the EM field experiences Brownian motion as it scatters virtual and thermal photons. Classically, the momentum imparted by the field fluctuations on the particle causes a momentum diffusion and drag experienced by its center-of-mass. When considering the dynamics of the quantized center-of-mass of the particle, these very fluctuations gain information about the particle's position, decohering its center-of-mass in the position basis, and dissipating energy. While the momentum diffusion and thermal drag for the classical center-of-mass are related by the fluctuation-dissipation relation, similar to the the decoherence and dissipation for the quantized center-of-mass -- in this talk we will demonstrate and discuss the connections between classical center-of-mass momentum diffusion and quantized center-of-mass decoherence rates. Our results illustrate a correspondence between classical and quantum Brownian motion of general polarizable particles, induced by fluctuations of the electromagnetic field.

Sara A Solla – Northwestern University
Low Dimensional Manifolds for Neural Dynamics
The ability to simultaneously record the activity from tens to hundreds to thousands of neurons has allowed us to analyze the computational role of population activity as opposed to single neuron activity. Recent work on a variety of cortical areas suggests that neural function may be built on the activation of population-wide activity patterns, the *neural modes*, rather than on the independent modulation of individual neural activity. These neural modes, the dominant covariation patterns within the neural population, define a low dimensional *neural manifold* that captures most of the variance in the recorded neural activity. We refer to the time-dependent activation of the neural modes as their *latent dynamics* and argue that latent cortical dynamics within low-dimensional manifolds are the fundamental and stable building blocks of neural population activity, and that they sustain neural information processing.

Jan Philip Solovej – University of Copenhagen
A model for periodicity of atomic structure
Despite its name the periodic table of the elements is not particularly periodic. It does nevertheless have the feature that that elements in the same group have similar chemical properties. The nobel gases He, Ne, Ar, Kr, … for example all have very weak chemical reactions. But if we imagine extending the periodic table to very large atomic number Z how would we predict which atoms are noble gases. The chemist have the somewhat phenomenological Aufbau Principle also known as the Madelung rule for determining the filling of electron orbitals in atoms. Fermi attempted to explain the Aufbau principle using the model in which an atom with atomic number Z is described by the one-particle Schrödinger Hamiltonian with the corresponding Thomas-Fermi mean-field potential. I will revisit this model and discuss a proof that for a sequence of atomic numbers Z_n tending to infinity these Thomas-Fermi mean field operators converge in strong resolvent sense if and only if CZ_n^{1/3} tends to a value \theta mod \pi for some explicit constant C. This shows that in this model atoms corresponding to such sequences in the limit have identical properties and that there is a certain periodicity. The Aufbau Principle would predict a similar result but with a different constant C. The result is based on a detailed WKB analysis. This is joint work with my Phd student August Bjerg.

Dave Thirumalai – University of Texas at Austin
Role of Condensin motors in Genome Folding
Condensation of hundreds of mega-base-pair-long human chromosomes in a small nuclear volume is a spectacular biological phenomenon. This process is driven by the formation of chromosome loops. The ATP consuming motor, condensin, interacts with chromatin segments to actively extrude loops. I will present an analytically solvable model for loop extrusion (LE) [1], which was motivated by real-time imaging experiments. The theory suggests that condensin must undergo a large conformational change, induced by ATP binding, bringing distant parts of the motor to proximity. Simulations using a simple model confirm that the motor transitions between an open and a closed state in order to extrude loops by a scrunching mechanism, similar to that proposed in DNA bubble formation during bacterial transcription. Changes in the orientation of the motor domains are transmitted over ~50 nm, connecting the motor head and the hinge, thus providing an allosteric basis for LE. Extension of the theory to multiple motors [2], which was used to obtain mitotic structures will be presented.

Pratyush Tiwary – University of Maryland, College Park
From chemical identity to Boltzmann ensembles for proteins, RNA and crystals with generative AI and statistical mechanics
Modern structure prediction tools using Artificial Intelligence (AI) have made great progress in predicting single dominant structures for generic proteins, RNA and crystals. However, chemistry is often more than a single structure, and involves carefully predicting an ensemble of structures with right fluctuations and thermodynamic weights. Here I will discuss methods from my group that, through combining generative AI with statistical mechanics and molecular simulations, allow predicting an ensemble of atomic resolution conformations together with correct Boltzmann ranking. The examples I show will likely include protein kinases, human RNA and crystal polymorph nucleation, where we will obtain thermodynamic and dynamic

observables such as drug residence times, conformational populations, effect of mutations, and melting curves starting solely from chemical identity and associated force-fields. I will conclude with thoughts on how chemistry, specifically classical thermodynamics and statistical mechanics have much to help design the next generation of AI methods meant for chemistry applications with all its quirks and richness.

Suriyanarayanan Vaikuntanathan – University of Chicago
"Active" associative memory.
Motivated by advances in the field of active matter where non-equilibrium forcing has been shown to activate new assembly pathways, we explore how non-equilibrium driving in prototypical memory formation models can surprisingly (and in general ways) affect their information processing capabilities. Our results reveal that activity can provide a new and surprisingly general way to dramatically improve the memory and information processing performance without the need for additional interactions or changes in connectivity. Non-equilibrium dynamics can allow these systems to have memory capacity, assembly, or pattern recognition properties, and learning ability, in excess of their corresponding equilibrium counterparts. These results are of significance to a variety of processes involving information storage and retrieval. They are also important for in silico learning and memory forming systems where nonequilibrium dynamics may provide an approach for modulating memory formation.

David Vanderbilt – Rutgers University
Theory of adiabatic phonon-magnon coupling in magnetic materials
Conventional approaches for computing lattice dynamics do not fully account for the effects of time-reversal symmetry breaking in magnetic systems. Recent approaches to rectify this involve incorporating the first-order force on each atom induced not only by the displacements, but also by the velocities, of other nearby atoms. The latter "emergent Lorentz forces" arise as the leading-order terms in adiabatic perturbation theory, and turn out to be governed by nothing other than the Berry curvature of the electronic ground state with respect to atomic displacements. Because the spin degrees of freedom ("magnons") evolve on a time scale that is similar to that of the lattice vibrations ("phonons"), a valid theory has to treat both on an equal footing. I will briefly describe the theory of these effects. Finally, taking CrI3 as a paradigmatic system, a few representative results will be reported.

Anna Vershynina – University of Houston
Quantum resource theory of coherence
Coherence describes the existence of quantum interference. We will discuss both static and dynamic quantum resource theory of coherence. Quantum resource theory considers some resources (states in the static theory and channels in the dynamic one) as free and the rest as a non-free resource. Accompanying these free resources are free quantum operations on them (quantum channel in the static theory and super-channels in the dynamic one), which leave the set of free resources invariant. The resource theory then studies information processing tasks that become possible using these operations. In this talk I will review the theory of coherence, as well as a relatively new dynamic resource theory of coherence. I will talk about the often used coherence measures of states, and will present new measures of the coherence of channels.

Simone Warzel – Technical University of Munich
The Parisi formula for quantum spin glasses
Classical spin-glass models such as Sherrington-Kirkpatrick's are paradigms for complex disordered systems. In 1980, Parisi described their thermodynamic behaviour using a novel order parameter that captures the emergent hierarchical spin-glass order at low temperatures. The fate of this low-temperature phase with respect to quantum effects induced by a transverse magnetic field is a fundamental question. In this talk, I will explain the features of a Parisi formula and its underlying order parameter for the free energy in the quantum case focusing on the example of the quantum Sherrington-Kirkpatrick model. Co-authored by C. Manai.

BingKan Xue – University of Florida
Input vs interaction modulation: Controlling networks to retrieve dynamic sequences
Many large systems, such as biological and engineered systems, exhibit well-controlled dynamics along a sequence of configurations. Such dynamics have been modeled using networks that sequentially retrieve a set of stored patterns. We reformulate some of these classic models and show that they belong to a general class in which the components of the system are controlled by a slow feedback ("input modulation"). In contrast, we introduce a new class of models in which the feedback modifies the interactions among the components ("interaction modulation"). We present several such models and show that they are capable of retrieving dynamic sequences. Among these, we find that modulation of symmetric interactions allows retrieval of patterns with different activity levels, is robust to feedback noise, and has a large dynamic capacity. Our results suggest that interaction modulation may be a new paradigm for controlling network dynamics.

Amanda Young – University of Illinois Urbana-Champaign
A bulk gap in the presence of edge states for a truncated Haldane pseudopotential
Haldane pseudopotentials were first introduced as Hamiltonian models for the fractional quantum Hall effect, and it has been long expected that they should exhibit the characteristic properties of this exotic phase of matter, including a spectral gap above the ground state energy. We will discuss recent work that verified this gap conjecture for a truncated version of the 1/3-filled Haldane pseudopotential in the cylinder geometry. Numerical evidence suggested that for open boundary conditions the gap of the truncated model closes as the cylinder radius converges to zero and that this closure is due to the presence of edge modes; in contrast, for periodic boundary conditions, the gap remains robustly order one in the same radius limit. The standard scheme for applying spectral gap estimating techniques to the model with periodic boundary conditions, though, produces a lower bound on the bulk gap that still reflects the energy of the edge modes. To obtain an estimate on the bulk gap that reflects its true behavior, a new gap estimating strategy was developed. By customizing the spectral gap method to key invariant subspaces of the Hamiltonian, we are able to successfully avoid the edge states and produce a more accurate lower bound on the bulk gap. In this talk, we discuss this invariant subspace strategy for proving bulk gaps in the presence of edge states. This is based off joint work with S. Warzel.

Nicole Yunger Halpern – National Institute of Standards and Technology
Beyond the first law: Peculiarly quantum conservation laws in thermodynamics
Starting in undergraduate statistical physics, we study small systems that thermalize by exchanging quantities with large environments. Such thermalization helps define time's arrow, and the exchanged quantities—heat, particles, electric charge, etc.—are conserved globally. If quantum, the quantities are represented by Hermitian operators. We often assume implicitly that the operators commute with each other—for instance, in derivations of the thermal state's form. Yet operators' ability to not commute underlies quantum phenomena such as uncertainty principles. What happens if thermodynamic conserved quantities fail to commute with each other? This question, mostly overlooked for decades, came to light recently at the intersection of quantum thermodynamics and information theory [1]. Noncommutation of conserved thermodynamic quantities has been found to enhance entanglement [2], decrease entropy-production rates, alter the eigenstate thermalization hypothesis [3], and more. This growing subfield illustrates how 21st-century quantum information science is extending 19th-century thermodynamics. [1] Majidy, Braasch, Lasek, Upadhyaya, Kalev, and NYH, Nat. Rev. Phys. (2023). https://www.nature.com/articles/s42254-023-00641-9 [2] Majidy, Lasek, Huse, and NYH, Phys. Rev. B **107** 045102 (2023). https://journals.aps.org/prb/abstract/10.1103/PhysRevB.107.045102 [3] Murthy, Babakhani, Iniguez, Srednicki, and NYH, Phys. Rev. Lett. **130**, 140402 (2023). https://doi.org/10.1103/PhysRevLett.130.140402