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041001 ***Colloquium*: Gene expression in growing cells: A biophysical primer**

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Gene expression, that is, the way in which genes encoded in the genome determine a cell's growth and biological function, is crucially influenced by growth-related processes, such as replication of the genome and the doubling of all cellular components. Historically, this interplay has been largely ignored. This Colloquium describes recent experiments designed to shed light on this important coupling and theoretical models that take it into account.

045001 **The science and technology of liquid argon detectors**

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Liquid argon detectors have reached an unprecedented level of maturity, owing to a couple of decades of R&D and the operation of large-scale facilities in several particle and astroparticle physics laboratories. After describing the physical and chemical properties of this noble element as an active and target medium for particle detection, the review discusses the opportunities and challenges of liquid argon detectors operated as calorimeters, scintillators, and time projection chambers. A comprehensive panorama of current and future applications is provided, ranging from collider physics to accelerator neutrino beam experiments and underground facilities for the observation of rare events, also including unconventional developments in medical and applied physics.

045002 **$\mathcal{PT}$-symmetric quantum mechanics**

Carl M. Bender
Daniel W. Hook

Historically, quantum mechanics is based on representing observables by Hermitian operators. All of that changed in 1998 when Bender and Boettcher showed that the spectrum of a Hamiltonian H can be real if H is $\mathcal{PT}$ symmetric, that is, symmetric under combined parity (space reflection) and time reversal. This has led to an explosion in theoretical and experimental research. This timely review covers the key developments in this exciting new field of physics.

045003 **Colloidal hard spheres: Triumphs, challenges, and mysteries**

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Hard spheres—simple particles that cannot overlap, like billiard balls—may at first glance seem to be a rather abstract model of matter. However, the development of well-controlled synthesis of suitable submicron colloids has realized hard spheres in experiment. When combined with modern light scattering and microscopy techniques to study colloidal hard spheres in reciprocal and real space, this model system has become pivotal to shedding new light on a wide range of fundamental physics, from hydrodynamics to phase transitions. This review provides a comprehensive guide to the multifaceted research on hard-sphere colloids, covering experimental, computational, and theoretical approaches both in and out of equilibrium.

045004 **New developments in the numerical conformal bootstrap**

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Conformal bootstrap has revealed itself in recent years as a powerful tool in the study of phase transitions. It has allowed the calculations of critical exponents with unprecedented accuracy in many models and it has been used to rule out some proposed second-order phase transitions. This article reviews the newest developments in conformal bootstrap and its numerical implementation.

045005 **Cosmological gravitational particle production and its implications for cosmological relics**

Edward W. Kolb
Andrew J. Long

Expansion of the Universe creates the conditions for particle production solely due to the presence of gravity. This review provides a field-theoretical description of particle creation in a time-dependent background and explores the consequences of cosmological gravitational particle production for dark matter, gravitational-wave radiation, dark radiation, and the baryon asymmetry of the Universe.

045006 **Semidefinite programming relaxations for quantum correlations**

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Sometimes a mathematical tool emerges as uniquely useful and even a defining feature within some branch of physics such as Feynman diagrams. In quantum information theory, the semidefinite program (SDP) has emerged as such a tool. SDP is an optimization task in which a linear objective function is maximized over a set of Hermitian matrices with positive eigenvalues. This review discusses the highly efficient algorithms available for the SDP, and shows how comprehensively the SDP has been deployed in problems of entanglement characterization, quantum nonlocality, quantum channel capacities, and the bounding of ground-state energies.

045007 **Kinetic solitary electrostatic structures in collisionless plasma: Phase-space holes**

I. H. Hutchinson

Plasma is usually taught to be a quasineutral gas of charged and neutral particles that exhibits collective behavior. However, satellites regularly observe solitary potential structures in space plasmas that are isolated positive or negative potential humps, called electron or ion holes. In the 1970s laboratory observations were made of electron holes. This review presents an overview of the observation of these electrostatic structures and presents their origin and their stability, using analytic theory and simulations. The role of kinetically unstable velocity distributions is identified as a key driver.

045008 **Wannier-function software ecosystem for materials simulations**

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The description of the electronic structure in terms of extended Bloch states has made it possible to understand and calculate many properties in condensed-matter physics. However, understanding and insight often require a local description, and Wannier functions provide an exact and insightful map of extended reciprocal-space Bloch states into localized real-space orbitals. Applications range far and wide—from ultra-accurate integrations to topological invariants—and their widespread uptake by the electronic-structure community has resulted in a growing and interoperable ecosystem of methods and associated software tools. This review provides a description of this ecosystem that has now become a major instrument for the electronic-structure community in its pursuit of understanding, discovering, and designing materials.