Dynamics of Collective Cells and Biological Tissues
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In this lecture I will present some recent advances in experimental and theoretical researches of the dynamic behaviors of biological tissues at multiple length scales. Particular attention is given to the biomechanical mechanisms underlying the morphodynamics of developing embryos and tumors. First, a multiscale chemomechanical model is established for the division of interconnecting cells in a biological tissue. Coupled mechanical-chemical mechanisms involved in the multi-phase cell division are taken into account. This model can well elucidate rich phenomena of cell divisions in embryos and tumors. Second, the spontaneous oscillation of collective cells in such biological tissues as Drosophila amnioserosa is investigated. It is revealed that the collective cell oscillation in an epithelium-like monolayer stems from the dynamic bifurcation induced by the feedback between mechanical strains and chemical cues. Third, we address, both experimentally and theoretically, the migration of collective cells. The migratory cells may behave as a whole either like a viscous solid or fluid, leading to rich patterns with characteristic sizes ranging from several to dozens of cells. The competition between intercellular interactions drives the cells to self-organize into various dynamic coherent structures. On the basis of experimental measurements and theoretical analysis, time-independent statistical laws are derived, which hold for all cell types we have observed in our study. The theory of entropy is used to decode the universality of the obtained scaling laws. Fourth, a thermodynamic theory is presented for the growth of solid tumors, which involves complicated coupling of mechanical, chemical, and biological factors. The tumors are treated as a porous growing medium allowing for nutrient and waste transport modulated by mechanical stresses. The morphological and structural evolutions of solid tumors are studied from the viewpoint of stability. The thermodynamic theory is also employed to analyze the enzymatic degradation of ECM that can effectively modify the tumor microenvironment to improve the efficiency of targeted-nanomedicine therapy of cancers.