The Logic of Complex Systems: Dynamics, Computations, and Thermodynamics

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Biochemistry provides a broadly valid representation for a world that is rather different from mechanics that describes point masses. Mechanically every molecule is different from every other molecules; two hemoglobin molecules are only statistically identical. Comparing and contrasting with Newtonian mechanics, we discover chemical kinetics and Gibbsian chemical thermodynamics should be identified as "kinematics" and "kinetics", respectively. Unfortunately, Gibbsian chemical thermodynamics is a theory without dynamics, nor a time-dependent equation. In this talk, using stochastic chemical kinetics as the starting point [1], with one elementary reaction at a time, we provide Gibbsian chemical thermodynamics a novel nonequilibrium dynamic foundation [2]. The new theory is applicable to both chemical equilibrium, mesoscopic and macroscopic, as well as open, driven chemical systems such as a single cell [3]. One significant application is a living cell and its phenotype switching. It provides cancer cell heterogeneity, Waddington developmental landscape, and neural computations a rigorous basis in terms of population kinetics [4].

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