APR13-2013-020103
Abstract for an Invited Paper
for the APR13 Meeting of
the American Physical Society

Universal Scaling Laws from Cells to Cities; A Physicist's Search for Quantitative, Unified Theories of Biological and Social Structure and Dynamics

GEOFFREY WEST, Santa Fe Institute

Many of the most challenging, exciting and profound questions facing science and society, from the origins of life to global sustainability, fall under the banner of "complex adaptive systems." This talk explores how scaling can be used to begin to develop physics-inspired quantitative, predictive, coarse-grained theories for understanding their structure, dynamics and organization based on underlying mathematisable principles. Remarkably, most physiological, organisational and life history phenomena in biology and socio-economic systems scale in a simple and "universal" fashion: metabolic rate scales approximately as the 3/4-power of mass over 27 orders of magnitude from complex molecules to the largest organisms. Time-scales (such as lifespans and growth-rates) and sizes (such as genome lengths and RNA densities) scale with exponents which are typically simple multiples of 1/4, suggesting that fundamental constraints underlie much of the generic structure and dynamics of living systems. These scaling laws follow from dynamical and geometrical properties of space-filling, fractal-like, hierarchical branching networks, presumed optimised by natural selection. This leads to a general framework that potentially captures essential features of diverse systems including vasculature, ontogenetic growth, cancer, aging and mortality, sleep, cell size, and DNA nucleotide substitution rates. Cities and companies also scale: wages, profits, patents, crime, disease, pollution, road lengths scale similarly across the globe, reflecting underlying universal social network dynamics which point to general principles of organization transcending their individuality. These have dramatic implications for global sustainability: innovation and wealth creation that fuel social systems, left unchecked, potentially sow the seeds for their inevitable collapse.