Robot Cancer: what the bioelectrics of embryogenesis and regeneration can teach us about unconventional computing, cognition, and the software of life

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Keynote Abstract

Today's engineered robots are often made from reliable yet dumb parts, which greatly limits their adaptive functionality but ensures that their subsystems do not defect from the overall purpose. In contrast, a key aspect of Life is that biological systems have competency at each level - they are made of collectives of cells, tissues, organs, etc. each of which has local goals, which orchestrates the noise and fragility at lower levels towards highly robust system-level behaviors. The cooperation and competition across scales in living systems results in great plasticity, and in basal cognition - memory and decision-making outside the brain that can provide essential inspiration for artificial life and robotics. In this talk, I will outline the remarkable properties of complex body regeneration in some species, in which cellular collectives remember and work toward a specific anatomical outcome. We have now uncovered some of the mechanisms by which cells represent target morphologies and execute the anatomical homeostasis that enables them to reach these goals despite radical perturbations. The mechanism of this error reduction loop and pattern memory is bioelectrical, and I will describe the new tools with which we can now directly read out these anatomical setpoints in all cell types. Best of all, we can now re-write them in vivo, producing lines of 2-headed flatworms and other drastically altered animal anatomies by brief modulation of the bioelectric patterning software running on genomically un-edited (wild-type) cellular hardware. By cracking the morphogenetic code and understanding how anatomical decisions are implemented by distribute bioelectrical computations in tissues, we get closer to our endgame: a reverse anatomical compiler that will enable top-down design of living form at the level of patterning modules, not by micromanaging the molecular machine code on which much of biology is focused today. I will conclude by sketching out the implications of this field for not only biomedicine but also for new machine learning architectures and for the creation of computer-designed living organisms. The future belongs to a deep consilience of computer science, cognitive science, and biology to understand the plasticity of multi-scale computational systems and greatly broaden the boundaries of life-as-it-could-be.