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The Evolution of Biological Complexity in Digital Organisms

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When Darwin first proposed his theory of evolution by natural selection, he realized that it had a problem explaining the origins of traits of "extreme perfection and complication" such as the vertebrate eye. Critics of Darwin's theory have latched onto this perceived flaw as a proof that Darwinian evolution is impossible. In anticipation of this issue, Darwin described the perfect data needed to understand this process, but lamented that such data are "scarcely ever possible" to obtain. In this talk, I will discuss research where we use populations of digital organisms (self-replicating and evolving computer programs) to elucidate the genetic and evolutionary processes by which new, highly-complex traits arise, drawing inspiration directly from Darwin's wistful thinking and hypotheses. During the process of evolution in these fully-transparent computational environments we can measure the incorporation of new information into the genome, a process akin to a natural Maxwell's Demon, and identify the original source of any such information. We show that, as Darwin predicted, much of the information used to encode a complex trait was already in the genome as part of simpler evolved traits, and that many routes must be possible for a new complex trait to have a high probability of successfully evolving. In even more extreme examples of the evolution of complexity, we are now using these same principles to examine the evolutionary dynamics the drive major transitions in evolution; that is transitions to higher-levels of organization, which are some of the most complex evolutionary events to occur in nature. Finally, I will explore some of the implications of this research to other aspects of evolutionary biology and as well as ways that these evolutionary principles can be applied toward solving computational and engineering problems.