MPIDS Colloquium

Topological scaling laws and the statistical mechanics of evolution

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For the last 3.8 billion years, the large-scale structure of evolution has followed a pattern of speciation that can be described by branching trees. Recent work, especially on bacterial sequences, has established that despite their apparent complexity, these so-called phylogenetic or evolutionary trees exhibit two unexplained broad structural features which are consistent across evolutionary time. The first is that phylogenetic trees exhibit scale-invariant topology, which quantifies the fact that their branching lies in between the two extreme cases of balanced binary trees and maximally unbalanced ones. The second is that the backbones of phylogenetic trees exhibit bursts of diversification on all timescales. I present a coarse-grained statistical mechanics model of ecological niche construction coupled to a simple model of speciation, and use renormalization group arguments to show that the statistical scaling properties of the resultant phylogenetic trees recapitulate both the scale-invariant topology and the bursty pattern of diversification in time. These results show in principle how dynamical scaling laws of phylogenetic trees on long time-scales may emerge from generic aspects of the interplay between ecological and evolutionary processes, leading to scale interference.

Finally, I will argue that these sorts of simplistic, minimal arguments might have a place in understanding other large-scale aspects of evolutionary biology. In particular, I will mention two questions where we do not have even a qualitative understanding let alone a quantitative one: (1) the spontaneous emergence of the open-ended growth of complexity; (2) the response of evolving systems to perturbations and the implications for their control. Even though biology is intimidatingly complex, "everything has an exception", and there are a huge number of undetermined parameters, statistical physics reasoning may lead to useful new insights into the existence and universal characteristics of living systems.

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Video conference at www.zoom.us
Meeting ID: 959 2774 3389
Passcode: 651129, direct link

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