Speed, Scaling, and Robustness in Biological Pattern Formation

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During embryonic development, complex and reproducible morphologies arise from a single fertilized oocyte despite substantial molecular noise. A range of mechanisms has been proposed to account for biological pattern formation, including reaction–diffusion systems, chemotaxis, differential adhesion, cell migration, and mechanical instabilities. In this talk, I will compare these mechanisms using quantitative models and analytical arguments, focusing on achievable pattern sharpness, formation speed, scaling with system size, and robustness to noise. The comparison highlights generic constraints on pattern-forming strategies and clarifies which mechanisms are compatible with developmental patterning under realistic biological conditions.