Chiral selectivity *vs.* noise in spontaneous mirror symmetry breaking

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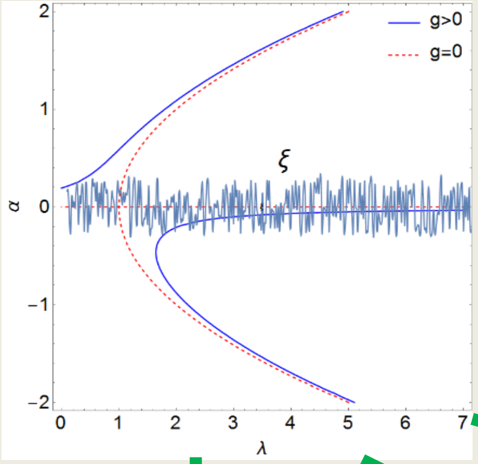
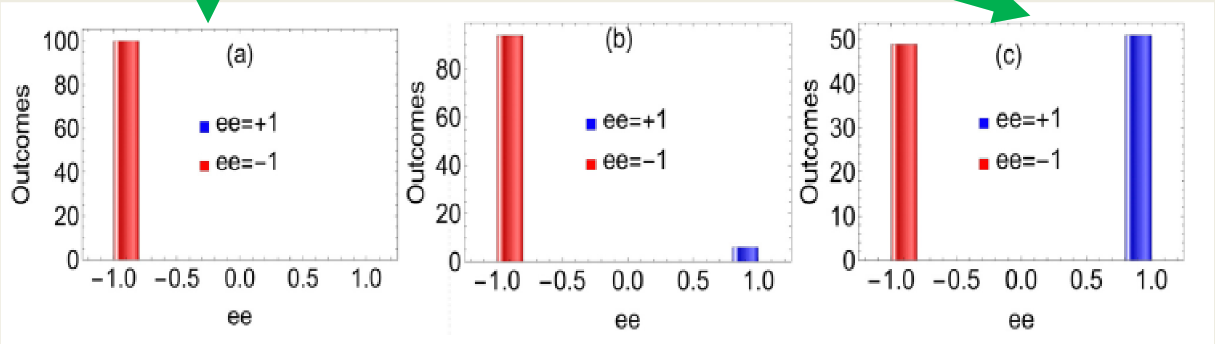


Imperfect bifurcation (blue curves) due to chiral bias g > 0 in presence of chiral fluctuations about the mirror symmetric state. Final chiral outcome (upper or lower blue branch) depends on relative strength of the bias g and the noise level ξ.



Final outcomes in terms of enantiomeric excess (ee): (a) when g > ξ , (b) for g = ξ, (c) for g < ξ. ee > 0 are right-handed outcomes, ee < 0 are left-handed. For 100 independent stochastic simulations.

Spontaneous mirror symmetry breaking (SMSB) in open systems is a crucial hypothesis for understanding the origin of biological homochirality. But the role of fluctuations versus chiral polarizations in systems capable of SMSB has received little attention. Enantiomers (left- and right-handed molecules) are classified as non-identical due to the violation of charge parity (CP) symmetry, resulting in a slight energy difference between them. This energy difference, known as the parity violation energy difference (PVED) is estimated to be much smaller than current experimental resolution. But this does not rule out the possibility of detecting PVED in a nonlinear macroscopic and non-equilibrium chemical system. In this paper we study a stochastic version of an open-flow autocatalytic reaction model capable of SMS subject to this PVED bias and temperature fluctuations.

Our findings demonstrate that when there is no chiral bias, the reaction rate constants used in the reaction model lead to an unstable racemic state, resulting in a fully random statistical racemic outcome. However, in the presence of PVED (or *any* weak chiral polarization), the system is not initially located on any specific branch but lies in the *basin of attraction* of the stable chiral branch, as determined by the chiral bias. Depending on the relative magnitudes of PVED and the temperature fluctuations, the PVED bias g can (a) deterministically select the final chiral outcome or (b) result in one of two possible chiral outcomes, with a statistically significant asymmetric bias towards the preferred chirality. If temperature fluctuations are sufficiently large, the PVED loses its chiral selectivity, leading to a fully random statistical racemic outcome (c). We also investigated the system's ability to maintain chiral selectivity against volume fluctuations and also against compositional fluctuations in the input flow channels to the reactor.

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