Speeding up RNA denaturation by cooling

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Zipping and unzipping dynamics of nucleic acids under temperature change or force have been studied for more than 50 years, with a renewed interest due to their potential use in nanotechnological applications. We show through extensive molecular dynamics simulations of a coarse-grained model that the unzipping time of RNA hairpins is a non-monotonous function of temperature for molecules longer than few persistence lengths, with an optimal temperature above the melting point, T_m, at which it occurs fastest. This anomaly arises from the existence of two distinct denaturation pathways, "unidirectional" and "bidirectional" unzipping which are preferred, respectively, immediately above the melting temperature and away from it. The two regimes manifest distinct scaling laws for the melting time *vs.* length, L, and are separated by a crossover temperature $T_\times$, with $(T_\times - T_m) \sim L^{-1}$. The results highlight the significant role of the helical structure in the out-of-equilibrium dynamics of RNA/DNA denaturation and predict a decrease in the unzipping time upon cooling in a temperature range wide enough to be experimentally observable for molecules with $\sim 10^2 - 10^3$ base pairs.

Reference: H. Li et al. PRL 134, 098401 (2025).