Kinetics and thermodynamics of molecular information processes

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Recent results in nonequilibrium thermodynamics and statistical mechanics are showing that directionality and dynamical order can manifest themselves as a corollary of the second law of thermodynamics in systems driven away from equilibrium by free energy supply. In molecular motors or autocatalytic reaction networks, nonequilibrium drive can generate motion or cyclic dynamical behavior. In this context, an important issue is to understand the kinetics and thermodynamics of molecular information processes. As already pointed out by Erwin Schrödinger in 1944, information can be coded at the molecular scale in copolymers, which are macromolecular chains composed of different species of monomeric units. Copolymerization processes are essential in chemistry, as well as in biology where genetic information is coded in DNA copolymers. In cells, genetic information is processed by template-directed copolymerization in DNA replication, the transcription of DNA into RNA, and the translation of RNA into proteins. Recent work shows that the kinetic equations ruling copolymerization processes can be exactly solved under low conversion conditions, even for templated-directed copolymerization. Furthermore, the thermodynamics of these processes is revealing that their entropy production rate depends on the mutual information between the template and its copy. These links between molecular information processing and the second law of thermodynamics are shedding a new light on genetic drift, mutations, and evolution.

References

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