Tryptophan Synthase: a Chemical Nanomachine

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The protein Tryptophan Synthase is an enzyme which performs synthesis of the essential tryptophan amino acid and is in use in all plants and bacteria (but not in animals). Its unique feature is that, in contrast to conventional enzymes, this single biomolecule implements a whole chemical reaction with multiple interdependent steps. The enzyme has two subunits (α and β), each with its own catalytic site. Inside the protein, they are connected by a 25 Å long tunnel through which the intermediate product of the α-site can be directly transported to the β-site. Uptake of substrates in the subunits and release of final products are controlled by two separate active gates. The operation of this enzyme involves a complex pattern of allosteric communication between the two active sites and the gates, leading to strong correlations and the synchronization of chemical events inside it. Thus, tryptophan synthase provides a characteristic example of a chemical nanomachine. It has attracted much attention and a large volume of experimental data for its individual process steps and conformational states is available. Employing the data, we have constructed a detailed kinetic single-molecule model of the enzyme which has allowed us to reproduce, for the first time, in stochastic numerical simulations the entire operation cycle of a chemical molecular machine.