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What is special about autocatalysis?

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Autocatalysis has never been popular in conventional chemical technology for two reasons: (i) autocatalysis results in positive feedback, which causes problems in controlling reactors, and (ii) autocatalytic systems may show complex dynamical phenomena often addressed as *nonlinear dynamics* like bistability, oscillations, deterministic chaos or spatial patterns, which are not desirable in chemical production. Since the second half of last century complex dynamics is in the center of interest and nonlinear dynamics based on autocatalysis has been and still is extensively studied by theory as well as experiment.

First and higher order autocatalytic processes are distinguished: (i) First order autocatalysis implies that a single autocatalytic molecule is involved in the process, e.g. $A+X \rightarrow 2X$. The phenomenon related to first order autocatalysis is selection in the Darwinian sense: All types of autocatalysts except one are eliminated in competitions. (ii) Second and higher order autocatalysis involves two or more autocatalytic molecules in the reaction, e.g. $A+2X \rightarrow 3X$. It gives rise to *nonlinear chemistry*, for example oscillations of concentrations or spontaneous formation of spatial patterns. Two important exceptions are common biological processes involving two partners but showing the only features of first order autocatalysis: plus-minus-replication and sexual reproduction. Biology contrasting chemistry is centered on autocatalysis in the form of reproduction. Multiplication of cells and organisms is the basis of evolution. A second and not less important feature of biology – again in contrast to chemistry – is the necessity to deal with stochastic phenomena caused by small and very small particle numbers. Every mutant, after all, starts out from a single copy.

In the lecture the detailed dynamical features that distinguish first order autocatalysis from ordinary chemical reactions will be presented and analyzed. Deterministic kinetics gives rise to selection that is unknown in conventional chemical kinetics. Fluctuations in first order autocatalytic processes have (at least) three different origins: (i) thermal fluctuations as in all common processes, (ii) anomalous fluctuations, and (iii) stochastic delay. Thermal fluctuations follow the conventional $\sqrt{N}$-law and do not require further consideration. The notion of *anomalous fluctuations* was coined in the nineteen-eighties by Tombesi, de Pasquale and Tartaglia in the analysis of stochasticity at bifurcations. Stochastic trajectories do not fulfill the uniqueness criterion and in case of bifurcations bundles of trajectories coming from the same alpha-limit may split and converge to different stationary states and this leads to bi- or multimodal distributions with very large variances. Stochastic delay is the result of discretization in time and concentrations, which causes a delay of stochastic trajectories in presence of self-enhancement at small particle numbers. Illustrative examples are taken from reactions in batch and flow reactors as well as from the logistic equation. The role of stochasticity in Darwin's principle of *selection of the fittest* will be discussed.