Chemical Systems: Large and Small

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Traditionally, synthetic chemistry has focused on the synthesis of molecules in a step-by-step fashion, whereby preparation of each intermediate is followed by time consuming and costly purification procedures. This strategy is in sharp contrast to how biological organisms operate large systems/networks of chemical reactions in synchrony and how they can synthesize various small molecules and macromolecules in massively parallel ways. Drawing inspiration from biology, one of the challenges for chemistry in the XXI century is thus to learn to assemble and control chemical systems rather than individual reactions. At present, we know precious little about wiring individual reactions into networks, building-in control elements into these networks (including non-linear interactions, feedback, etc.), or "programming" their overall functions.

My talk will illustrate a two-pronged effort aimed at making chemical systems an experimental reality. The bottom-up approach focuses on combining individual chemical phenomena into entities of increasing complexity. Examples here will include the coupling of chemical oscillators to self-assembly phenomena involving small molecules or nanosized objects. The influence of system's geometry on its function will also be discussed. In the top-down approach, I will illustrate how we can prune the existing body of chemical knowledge to identify chemical network "motifs" that can act as stand-along chemical systems. This part of the talk will introduce algorithms that allow for automated identification of sequential reactions, which can be performed in one flask without the need for intermediate purification.

The overall message I hope to convey is that by combining experiments with theory, it is possible to synthesize not only individual molecules but chemical systems of increasing complexities and acting on different length scales.