From Chemical Topology to Molecular Machines

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This lecture will provide an historical perspective of the field known as "chemical topology". The link between catenanes or rotaxanes and molecular machines will also be stressed.

The area named "Chemical Topology" is mostly concerned with molecules whose molecular graph is non-planar, i.e. which cannot be represented in a plane without crossing points. The most important family of such compounds is that of catenanes. The simplest catenane, a [2]catenane, consists of two interlocking rings. Rotaxanes consist of rings threaded by acyclic fragments (axes). These compounds have always been associated to catenanes although, strictly speaking, their molecular graphs are planar. The simplest rotaxane, a [2]rotaxane, contains two non-covalently connected components : a ring and an axis, the axis being end-functionalised by bulky groups preventing unthreading of the non cyclic fragment from the cycle. Interlocking ring compounds (also named "Mechanically Interlocked Molecules") have attracted much interest in the molecular sciences, first as pure synthetic challenges and, more recently, as components of functional materials. The synthesis of such compounds relies on templates (transition metals or organic assemblies). In recent years, spectacular progress has been made. Highly functional and complex systems have been reported by several research teams, demonstrating the power of modern synthetic tools based on "template effects". Promising materials have also been elaborated which contain interlocking ring compounds. A few examples will be discussed.

Separately, the field of artificial molecular machines has experienced a spectacular development, in relation to molecular devices at the nanometric level or mimics of biological motors. In biology, motor proteins are of the utmost importance in a large variety of processes essential to life (ATPase, a rotary motor, or the myosin-actin complex of striated muscles behaving as a linear motor responsible for contraction or elongation). A few recent examples are based on simple or more complex rotaxanes or catenanes acting as switchable systems or molecular machines. Particularly significant examples include "molecular shuttles" as well as multi-rotaxanes reminiscent of muscles or able to act as switchable receptors. The molecules are set in motion using electrochemical, photonic or chemical signals. Examples will be given which cover the various approaches used for triggering the molecular motions implied in various synthetic molecular machine prototypes. Finally, light-driven molecular machine prototypes based on ruthenium(II) complexes will be discussed.