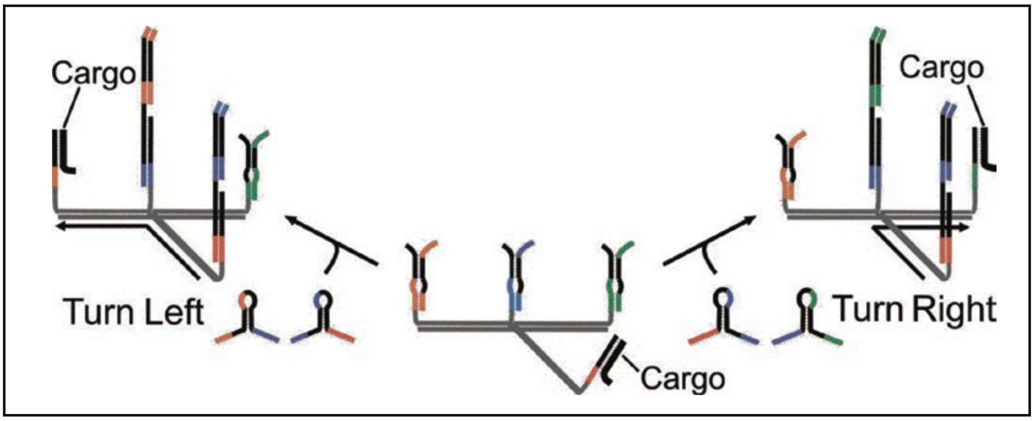
DNA nanotechnology

Andrew Turberfield and Ard Louis



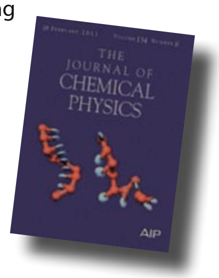
A schematic of a programmable molecular robot made of DNA

Oxford researchers are harnessing the specific pairing of DNA bases to create dynamic structures at the nanoscale. Short strands of DNA can be bought (online!) and by carefully designing their sequences, coaxed into a wide variety of well-defined shapes by exploiting the physics of hybridisation. DNA can also act as an addressable glue to join components, it can provide scaffolding support for other nano-structures and it can even act as fuel for molecular engines. Potential applications of this technology include chemical assembly lines, electronic circuits and responsive drug delivery systems.

Andrew Turberfield is one of the pioneers of this emerging field of DNA nanotechnology and with Jon Bath and students in his group in the Clarendon Laboratory has recently published two papers, in *Nature Nanotechnology* and *Nano Letters*, describing DNA-fuelled molecular motors. Shelley Wickham, who has just defended her DPhil, reported a DNA walker that can walk autonomously along a 100 nm long prefabricated track in 16 consecutive, precisely controlled steps. Atomic force microscopy allowed collaborators in Kyoto University to make the first real-time observations of these steps. Richard Muscat designed a "programmable molecular robot" that can carry a molecular cargo along a pre-programmed trajectory through a branching system of tracks. One of the long-term goals of this work is to create cell-scale modular architectures that could be programmed into a molecular assembly line to create an autonomous molecular manufacturing system.

When Ard Louis joined the Rudolf Peierls Centre for Theoretical Physics in 2006, he began, inspired by work in the Turberfield group, a project to model DNA nanostructures, with his long-standing collaborator Jonathan Doye from Physical Chemistry and DPhil student Tom Ouldridge. Their goal was to develop a coarse-grained model that is simple enough to be tractable, but complex enough to capture structural, thermodynamic and mechanical properties of DNA that are crucial to DNA nanotechnology. By focusing on the basic physics of single strands, double strands, and the transitions between them, they were able to describe a number of the underlying physical processes that are exploited when experimentalists make things from DNA. Their first success was a computer simulation of the complete cycle of DNA tweezers, one of the first molecular machines constructed by self-assembly by Andrew Turberfield and collaborators. A detailed description of the method was selected for the cover of the *Journal of Chemical Physics*.

There is now a very active collaboration between theorists in the Rudolf Peierls Centre, in Theoretical Chemistry and the experimental DNA group in the Clarendon Laboratory. By using computer simulations, many processes that are inaccessible to experimental measurement can be carefully examined. At the same time, detailed analysis of the experiments helps constrain and improve the theoretical models. DNA is a wonderful material with which to build, and DNA self-assembly is a meeting point for soft matter physics, nanometre-scale engineering and molecular biology.



A picture of the DNA model created by Tom Ouldridge et al.

Self-assembly of DNA tetrahedra