Diverse and robust molecular algorithms using reprogrammable DNA self-assembly

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Algorithmic self-assembly is a form of molecular computation where molecules attach to a growing nanostructure and where each attachment event executes a logical instruction step of the computation. In recent work [1] we have designed a reprogrammable set of 355 DNA strands, or tiles, capable of implementing a wide variety of self-assembly algorithms. Each algorithm is programmed by choosing a subset of the DNA strands. In this way, we implemented a total of 21 6-bit algorithms, including bit-copying, sorting, recognizing palindromes and multiples of 3, random walking, obtaining an unbiased choice from a biased random source, electing a leader, simulating cellular automata, generating deterministic and randomised patterns, and serving as a period 63 counter. The average per-tile error rate over the 21 different algorithms was less than 1 in 3000.

Having a reprogrammable architecture enabled programming while at the bench: we could come up with a new algorithm and implement it on the same day. Just like laptops can be reprogrammed using high-level programming languages, and without knowledge of the underlying device physics or processor instruction sets, users of our self-assembly system can design and run molecular algorithms without needing to know the intricacies of our design pipeline. Development of multipurpose molecular machines, reprogrammable without knowledge of the machine's physics, could establish a creative space where high-level molecular programmers can flourish.

[1] Damien Woods*, David Doty*, Cameron Myhrvold, Joy Hui, Felix Zhou, Peng Yin, Erik Winfree (*joint first co-authors). Diverse and robust molecular algorithms using reprogrammable DNA self-assembly. Nature. 2019