A Proximity-Based Programmable DNA Nanoscale Assembly Line

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We build products on the macroscopic scale by orienting and juxtaposing components, and then performing an operation (e.g., welding, bolting, gluing or sewing) to get them to cohere; for a complex machine, such as an automobile, both juxtaposition and fastening are done on an assembly line. Chemical synthesis differs from macroscopic assembly, because the precursors collide in all possible orientations, yielding products according to the laws of quantum mechanics and thermodynamics. One of the potential strengths of nanoscale assembly using information-containing molecules is that it holds the promise of stepwise and programmed construction of target products by orienting and fastening individually selected components along an assembly line. Here, we combine known DNA modules to build a programmable assembly line. Assembly lines require three components: [1] Devices that can be programmed to add a component to the product; [2] a conveyor to move the growing product to the next station; and [3] a framework to position and orient the conveyor and devices. We have used a series of three cassettes containing independently-controlled two-state DNA machines as programmable devices; a novel DNA walker is the conveyer; by inserting the device-bearing cassettes into a DNA origami tile, we provide a framework and a track for the walker. As the walker traverses its pathway, it encounters sequentially the three devices containing component cargoes that can be added to the walker. The basis for the programmability of the system is proximity for reactivity and distance for protection: The state of each device establishes whether its cargo component is close enough to the walker for it to be added. The components are gold nanoparticles, so three devices enable eight different configurations of nanoparticles to be programmed.

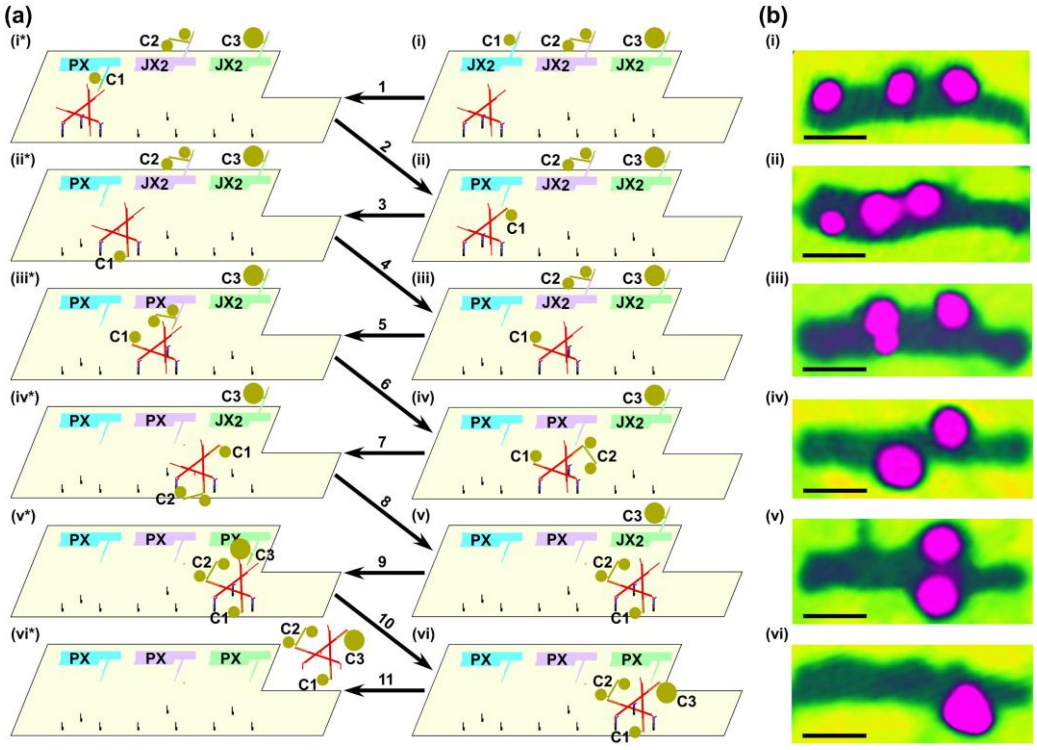

Figure 1. *The Steps in Assembly of the Triple Addition Product.* Schematics are shown in (a) and atomic force micrographs of the right column of (a) are shown in (b). AFM was performed by tapping in air; this mode of AFM results in only the nanoparticles and the origami being visible, and the individual nanoparticle components are not resolved from each other. Owing to the washing procedures between steps, the AFM images are not of the same individual assembly line. All scale bars are 50 nm.

This research has been supported by NIGMS, NSF, ARO, ONR, and W.M. Keck Foundation, as well as NBRP of China.