Molecular transport through self-assembled DNA nanofluidic channels

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Nanoscale channels are a fundamental mechanism for directed transport within living systems. Confinement of transport to one dimension makes transport rapid, and gating at channel entrances can make transport selective. However, little is known about the mechanisms and rates of transport of small molecules within nanoscale channels, particularly those that extend beyond the dimensions of lipid membranes and across hundreds of nanometers or microns.

We have used techniques from structural DNA nanotechnology, which makes it possible to precisely control the geometry and chemical functionality of self-assembled structures, to construct synthetic nanoscale channels for molecular transport. The channel we have designed and constructed has an internal diameter of 4-6 nm and a length that can extend for multiple microns. It is composed of a DNA origami pore that penetrates and spans a lipid membrane and a DNA nanotube self-assembled from DAE-E double crossover tiles, consisting of five DNA oligomers that grows from the DNA origami pore. Membrane incorporation is facilitated by hydrophobic functionalization of DNA origami pore via 12 cholesterol moieties. These self-assembled channels can self-repair and can be grown such that their endpoints specifically attach at molecular landmarks, making them a promising biomolecular devices for single-molecule biosensing, for studying intercellular signaling, and for drug delivery.

We characterized molecular transport through these DNA channels by confocal microscopy and a dye influx assay, in which synthesized DNA channels spontaneously inserted onto giant unilamellar vesicles. The rates of fluorescent dye transport through the channels were quantified by time-lapse observation of intensities inside many vesicles through a confocal microscope and comparing to a diffusion-dominated molecular transport model. Our results indicate that transport of small molecules through these channels is diffusive and that molecule size determines the degree to which transport may occur.

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