DNA-based reaction-diffusion waves within microfluidics

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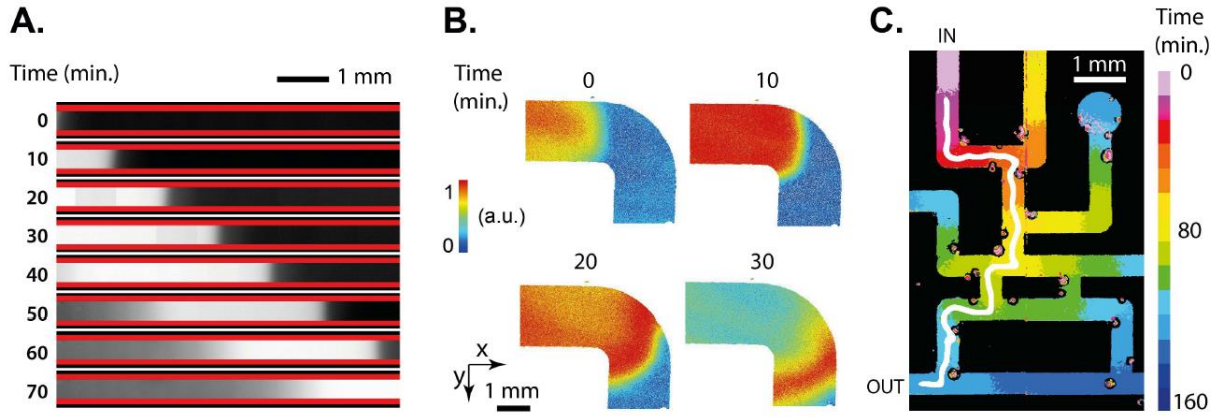

Figure: A. A pulse of preys propagates in a straight channel. B. A pulse of preys propagates in a 90° turn; path difference in between the inner path and outer path is compensated by lateral diffusion. C. A pulse of preys propagates through an arbitrary maze. Pulse propagation over time is color-coded, making possible to solve the maze (white line) by reverse analysis.

Macroscopic spatiotemporal order in biological systems arises from complex reaction networks that involve microscopic biochemical species. In this work, we employed a simplified biochemical tool kit of 2 enzymes and 3 DNA species under well-defined conditions to investigate the propagation of chemical waves generated in arbitrary geometries.[1]

We first studied the temporal dynamics of a network exhibiting a predator-prey mechanism, where predators and preys were short DNA strands. Furthermore, we exploited the advantages of microfluidics, through its high spatial and temporal resolution in fluid handling, to design one and two dimensional reactors, and precisely define initial conditions and boundaries. We observed travelling wave of preys followed by a front of predators in straight and turn channels (figure A and B). Wave velocity measurements ranged from 30 $\mu m.min^{-1}$ to 70 $\mu m.min^{-1}$ depending on enzyme concentration, and was in agreement with a previously proposed reaction-diffusion model.[2]

We also succeeded in computing the spatial solution of an arbitrary maze design (figure C.). Wave of preys – initiated upper-left “IN” – propagated through all possible paths, splitting at each crossing, vanishing at dead ends and collapsing when two waves collide.

Together, reconfigurable DNA-based synthetic networks and microfluidics, can open new routes to explore emergence of large scale spatiotemporal order from interacting biomolecules. We aim to generate, through the control of DNA strand diffusion coefficient,[3] stable patterns such as the famous Turing patterns, credible pictures for the chemical basis of morphogenesis.

(1) Zambrano, a.; Zadorin, a. S.; Rondelez, Y.; Galas, J.-C.; Estévez-Torres, A.; Galas, J.-C. Pursuit-and-Evasion Reaction-Diffusion Waves in Microreactors with Tailored Geometry. *J. Phys. Chem. B* **2015**, 150415150857008.

(2) Padirac, A.; Fujii, T.; Estévez-Torres, A.; Rondelez, Y. Spatial Waves in Synthetic Biochemical Networks. *J. Am. Chem. Soc.* **2013**.

(3) Zadorin, A. S.; Rondelez, Y.; Galas, J.-C.; Estevez-Torres, A. Synthesis of Programmable Reaction-Diffusion Fronts Using DNA Catalyzers. *Phys. Rev. Lett.* **2015**, *114*, 068301.