# Chemical basis for minimal cognition

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We have developed a simple chemical system capable of self-movement in order to study the chemical-molecular origins of movement, perception and cognition. The system consists simply of an oil droplet in an aqueous environment. The aqueous phase contains a surfactant that modulates the interfacial tension between the drop of oil and its environment. We embed a chemical reaction in the oil phase that reacts with water when an oily precursor comes in contact with the water phase at the liquid-liquid interface. This reaction not only powers the droplet to move in the aqueous phase but also allows for sustained movement. The direction of the movement is governed by a self-generated pH gradient that surrounds the droplet. In addition this self-generated gradient can be overridden by an externally imposed pH gradient, and therefore the direction of droplet motion may be controlled. Also we noticed that convection flow is generated inside the oil droplet to cause the movement, which was also confirmed by simulating the fluid dynamics integrated with chemical reactions (Matsuno et al., 2007, ACAL 07, Springer, p.179, Springer). We can observe that the droplet senses the gradient in the environment (either internally generated or externally imposed) and moves predictably within the gradient as a form of primitive chemotaxis (Hanczyc, M., et al., 2007, J. Am. Chem. Soc., 129, p. 9386).

By creating a pH gradient and concomitant convection flow, the droplet behaves as if it can perceive the environment. We believe that the geometry of the interface shape can control sensitivity to the environment (Ikegami et al., 2008, BioSys., 91, p.388). This geometry-induced fluctuation is the source of fluctuation of motion, which we think is tightly linked with the idea of biological autonomy. There is empirical evidence to support the above ideas. Some form of internal bias is necessary for breaking symmetry to cause self-movement and the bias may be the result of perception of the environment.

Such simple oil droplet systems show autonomy in the sense that the droplets move in response to the self-generated pH and the environmental gradient. In our modeling, we demonstrated that a computational autopoietic cell could move by continuously self-repairing the membrane, but in this case failed to show any gradient-climbing behavior (Suzuki et al., 2008, Artificial Life, in press). This may be due to the fact that the autopoietic cell can only survive in the narrow range of environments that support a certain substrate density. Compared with that autopoietic cell model, our oil droplets are more stable and they strive to maintain their boundary structures. We hypothesize that the pH gradient around the droplet results in an unbalanced interfacial tension at the interface. The droplet then responds by motion in order to maintain a balanced interfacial tension. Once the tension forces around the droplet are balanced the droplet would stop moving. In this way, we contend that a kind of homeostasis is a basis for self-movement. Different from the mere physical-chemical process, any life system preserves its own identity and consistency with respect to the environment. This homeostasis, rooted on the sensory motor couplings, will organize minimal cognition (see also, Ikegami , T. et al., 2008, BioSys., 91, p.388 ]