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# A New View of Protocell Metabolism

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Chemical reaction networks can exhibit interesting non-linear dynamics in reaction contexts with variable solvent volume (Pawłowski and Zielenkiewicz, 2004; Lizana et al., 2008), although this possibility has received little attention in the literature. Lipid vesicles, the standard chassis for many prebiotic protocell models, are compartments which enclose a water pool of variable volume. The semi-permeable nature of the lipid bilayer membrane facilitates, by the mechanism of osmosis, a flow of water entering or leaving the internal pool of the vesicle whenever there is a disequilibrium in the total solute concentration inside and outside (Oglecka et al., 2012). Therefore, the volume of a vesicle is not only variable, but is also determined as a function of the reaction dynamics ongoing inside the vesicle.

This contribution reviews and extends the findings of a new theoretical study (Shirt-Ediss et al., 2015) investigating novel non-linear behaviour which can arise when simple chemistry, that by itself is uninteresting, is encapsulated inside model lipid vesicles with osmotically-changing solvent volume (Figure 1). These findings could be relevant to the origins of life, at a stage when vesicles moved away from equilibrium and turned into the first chemical nano-reactors.

In particular, a new principle called *osmotic coupling* is to be put forward. Osmotic coupling refers to the potential of osmosis to *indirectly* couple two or more chemically-independent reaction networks operating inside a lipid vesicle. The coupling results because, despite not having any chemical species in common, the reaction networks happen to share the same variable volume reaction space, which their chemical concentrations jointly determine the size of. In this way, a larger chemical system with potentially very complicated dynamics may be created from simpler pieces.

This view of proto-metabolism, as a series of indirectly coupled but otherwise chemically inert subsystems, represents an interesting departure from the traditional dogma of proto-metabolism as one single connected set of chemical transformations (e.g. as in Ganti's Chemoton). Furthermore, it could be more realistic, considering that prebiotic vesicles would have assembled in diverse chemical mixtures hosting potentially unrelated reaction processes.

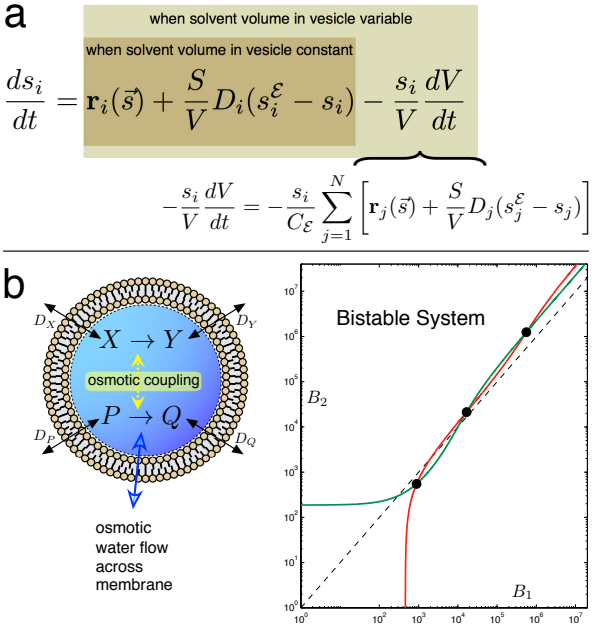


Figure 1: Changing solvent volume inside a vesicle **(a)** theoretically introduces more non-linear terms to the concentration dynamics of each internal species and **(b)** can give rise to the emergence of new steady states, via osmotic coupling.

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