

Avenues for Emergent Ecologies

We sought to explore the phenomenological transition from physico-chemical to biological. What kind of mesoscopic logic is required for ecological behaviour to emerge? This investigation made use of the artificial chemistry framework of Ono (2005). The system consisted of discrete particles moving and reacting on a 2D lattice. The reaction network is shown in figure 1. The chemical states of particles were driven round these cycles by a combination of enthalpy gradients, catalysis and forcing from an external energy source. X particles are pre-cursors and Y particles are low enthalpy waste products. M particles undergo separation from water and mutual alignment due to a hydrophobic effect. A and B particles are hydrophilic catalysts.

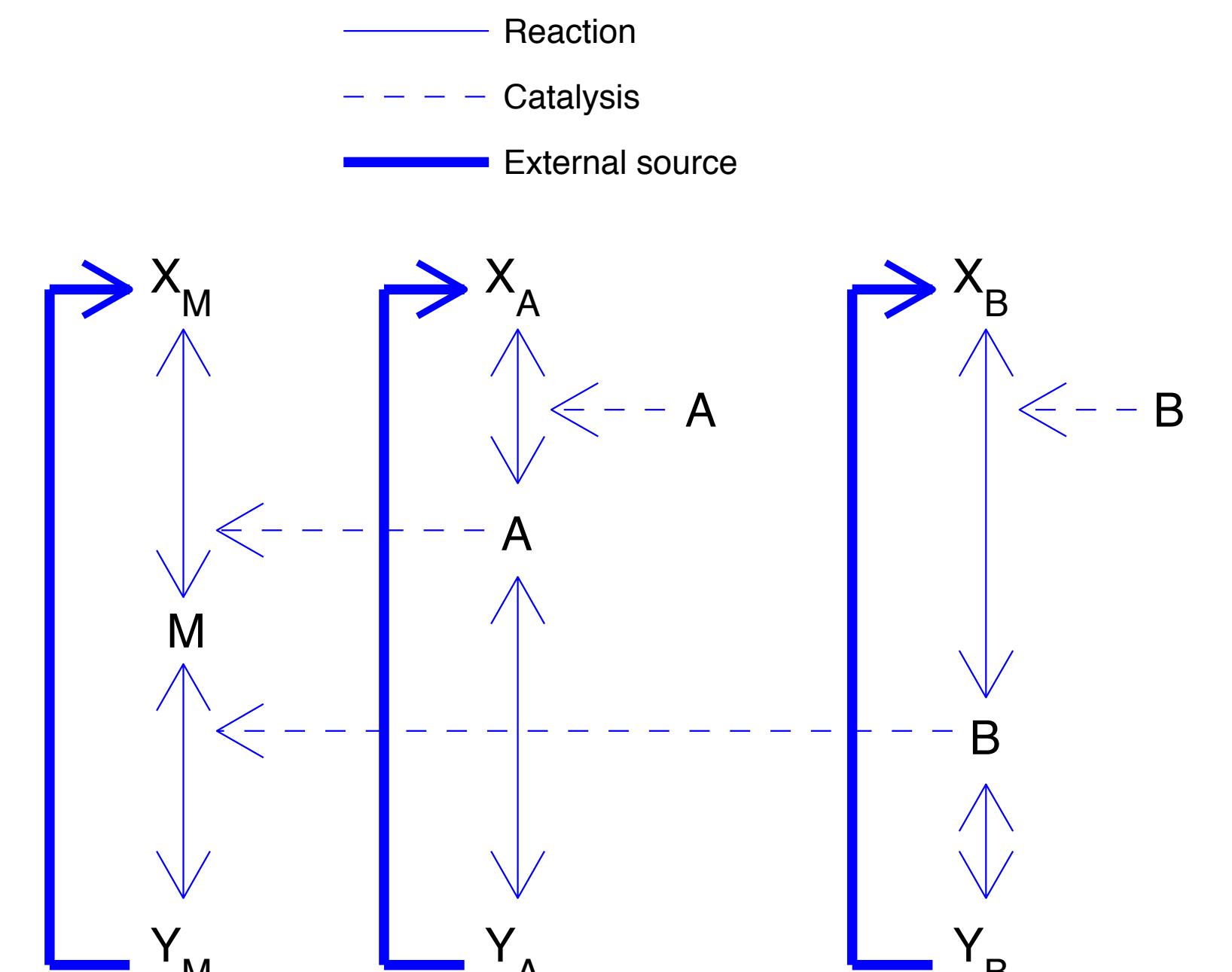


Fig 1. System reaction network. Particle enthalpy increases approximately with height in this diagram.

In the absence of B catalyst particles, enclosed, autopoietic structures form, grow and divide, as shown in figure 2.

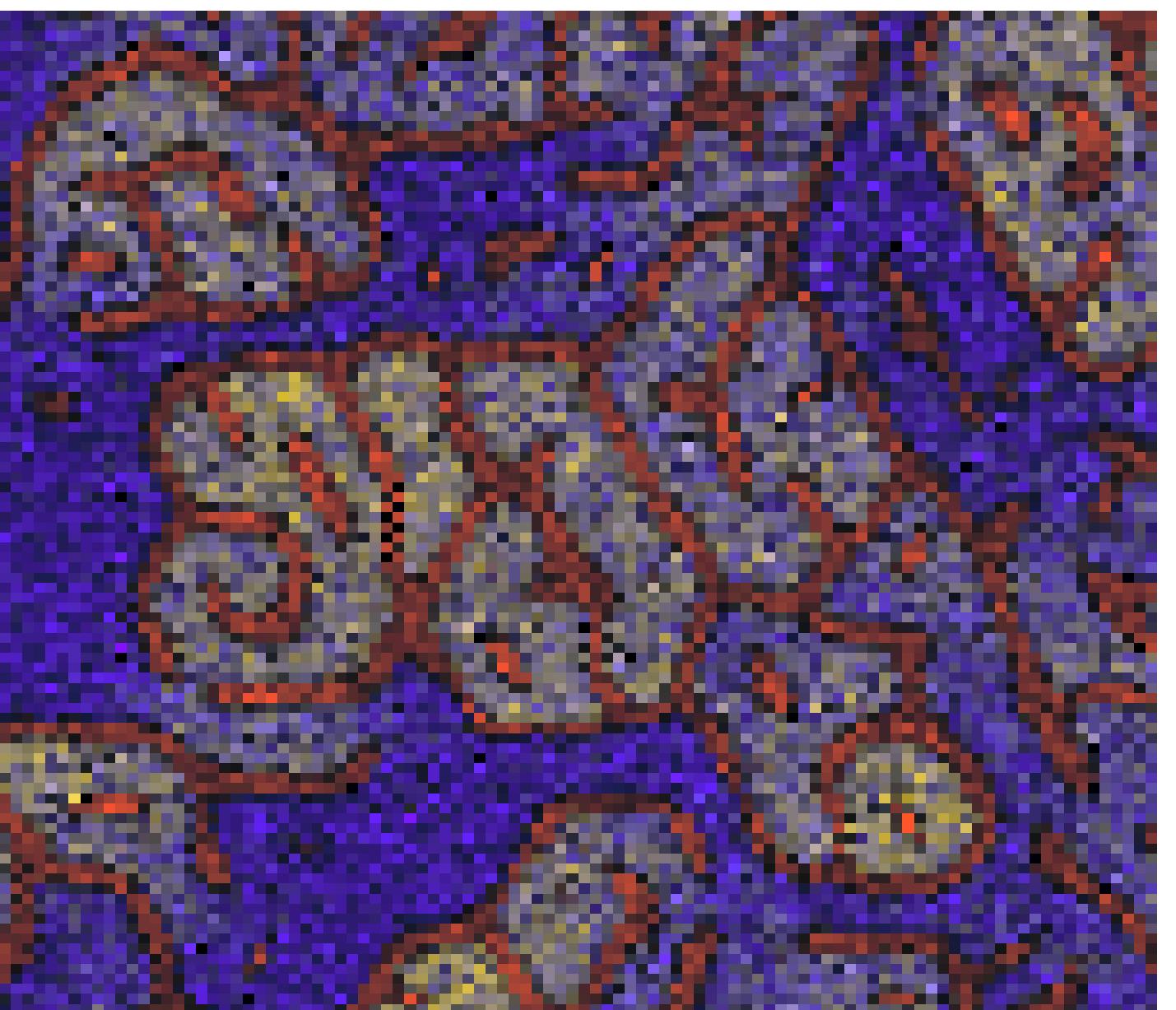


Fig 2. Emergence of autopoietic units as demonstrated in the original work of Ono (2005). M and A particle densities correspond to depth of red and orange respectively.

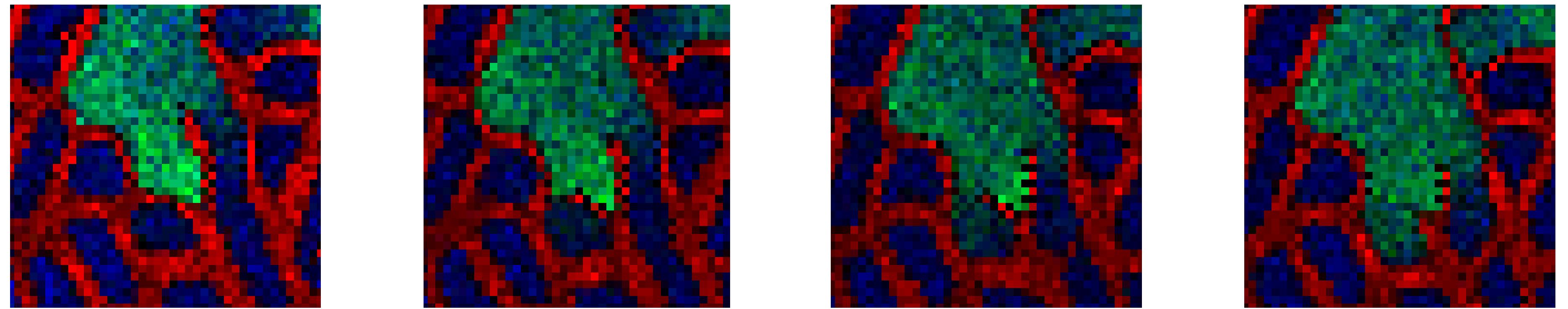


Fig 3. A group of protocells being invaded by B particles, which grow exponentially in concentration when isolated since there is very little outward diffusion due to the hydrophobic barrier provided by M particles. Note that only membrane, B-particle and water concentrations are shown in these images.

But when the second catalyst is added a new meso-level logic emerges. Due to their non-linear, auto-catalytic properties, B particles find a niche within membrane-bound regions. Here the concentration grows exponentially due to the significant reduction in outward diffusion caused by the presence of the M particles. However there is also a rapid and simultaneous erosion of the local membrane. Nearby protocells are thus forced to grow away from any prevailing B-particle cloud. Colony formation is the only means by which protocells can survive in any number but this continues to provide isolated regions in which B particles flourish. This dynamic resonates indefinitely as the colony of cells is pursued across the simulation domain. At large length scales, the colony appears to envelope the B-particle cloud. This seems to be a means to maximise cell number in the face of the destructive effects of the cloud.

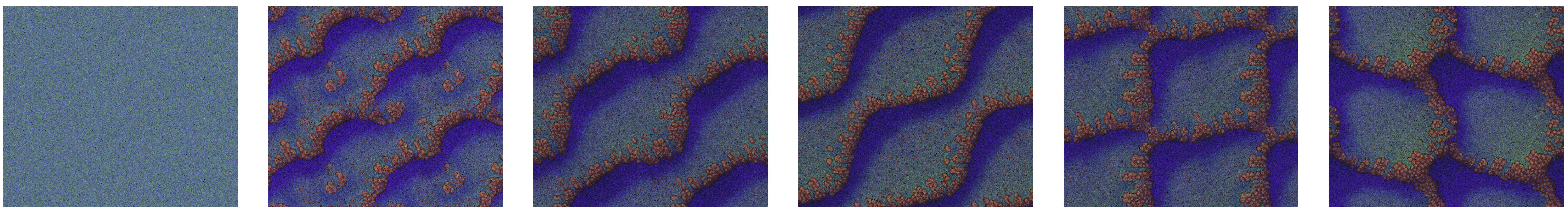


Fig 4. Large scale, long time system behaviour. At first the colony forms into waves but then surrounds the B-particle cloud. Note that these images were produced by amalgamating four copies of the system's state to give a better long range perspective. This is possible due to the periodic boundary conditions used.

In this work we have observed the emergence of ecology-like behaviour from a purely physical system. Selection pressure is not pre-defined but simply arises from free energy minimisation. This suggests that ecological principles may have pre-dated the existence of biological organisms.

View an animation of this simulation at: <http://tinyurl.com/nwbs83n>

1. Ono, N. (2005) Computational studies on conditions of the emergence of autopoietic protocells. *BioSystems*, 81:223-233.

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