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Experimental studied on growing chemical organisms.

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The subject of this conference is: 'Attempts to design and build artificial systems that display properties of organisms'. Two hundred years ago, the philosopher Immanuel Kant wrote the following:

'Property of life: A self-propagating organization of processes.'

The difference between biological organisms and the complex chemical systems made by humans cannot be underestimated. The former contain such a large number of physical and chemical processes, each marked by incredible spatial and temporal organization and preciseness, that as of yet, their artificial reproduction is unachievable.

There remains, in addition, a gulf between biological growth and human controlled technology. These methods are not compatible. Human built complex chemical systems are assembled, whereas the biological systems are grown. Even the simplest biological cell cannot be disassembled and later reconstructed as if it were an AK-47.

Few known phenomena show promise of bridging this gulf; one of these is the 'Chemical Garden'. In such systems, chemical reactions between a few elements drive fluid flow to spontaneously form precipitation structures. These structures can be grown from a 'seed`, and the specific structure produced closely correlates to the composition of the seed and the environment. Chemical gardens have growth trajectories that span a vast morphological space, which includes hierarchical structures and also structures that move (chemical motors).

Among the first works devoted to these systems was published by Leduc in 1911 under the title "The Mechanism of Life"[1]. Leduc recognized the similarity of chemical gardens with biological systems and believed that this similarity could teach us something about the origin of life. In his book, he wrote that "The study of synthetic biology is therefore the study of physical forces and conditions which can produce cavities surrounded by osmotic membranes… and specialized their functions of living beings."
Examples of the structures that can be grown in this manner are presented below.

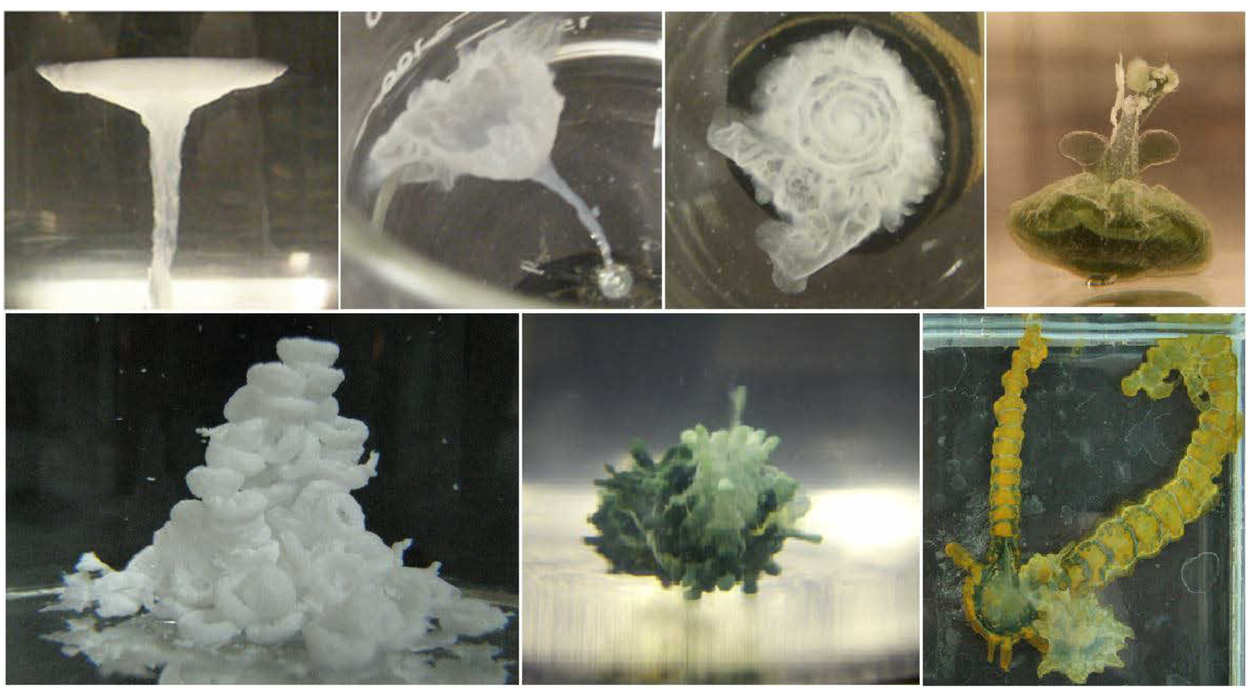

Figure1: Examples of complex structures that grow in simple chemical systems.

In each of these systems, growth is controlled by a complicated network of precisely organized physical and chemical processes. This growth is caused by a chain reaction; different potential gradients form structures that are, in turn, sources of new potential gradients. Thus we have a sequence of structures and processes: Structure follows process, gradient follows process, structure follows gradient, and so on. In these complex networks, different trajectories lead to different structures. Trajectories can be controlled by environment or seed composition. The growing process is often characterized by formation of templates that control formation of the next structure. The template may, depending on the trajectories, form different structures. Some structures may undergo metamorphosis where the entire structure changes (copper-oxalate system).

The process of growth is hierarchical, forming a network. Simple elements at lower levels form more complex structures at the higher levels. These, in turn, function as simple building blocks for even higher levels. So far, we have grown chemical systems with eight hierarchy levels. This is only the beginning. By changing system parameters, we can form different chemical building blocks, thus changing the trajectory. Trajectories may also be changed by catalysts or inhibitors (aluminum silicate system).

In most cases, the growing network can be divided into three parts: the seed, the construction, and the final structure. The seed forms an initial cell, where the initial potential gradients are making initial processes. The next part of network is construction, where the cascade of different structures are built. These systems are open ended, making it impossible to predict the final structure. Usually, the structure is finalized when the network has a loop that results in termination of structure growth.

Sometimes we observe the formation of a whole that may perform certain tasks. This part of the network is operational. It controls the task. Examples are cells that move up and down. This process is controlled by many chemical and physical sub-processes forming a loop (aluminum-carbonate-hydroxide system). Under another condition, this system may construct more complex structures that remain, made by humans, complex curtains.

The Chemical Garden and related structures are chemical systems bridging living and nonliving matter. They allow us to study a much simpler analogue to biological systems. The difference is the lack of DNA and genetic-informational systems that have very complex functions and control mechanisms. It may be said that chemical organisms are biological systems where DNA has been removed after formation of all proteins.

Mastering the growth of these complex chemical organisms may be the beginning of a new technology.

The following papers describe the presented phenomena:

Maselko, J., and P. Strizhak. 2004. Spontaneous formation of cellular chemical system that sustains itself far from thermodynamic equilibrium. Journal of Physical Chemistry B, 108, 4937 - 4939, doi:10.1021/jp036417j (2004).

Vladimir V. Udovichenko[1], Peter E. Strizhak[1], Agata Toth[2], Dezso Horwath[2], Steven Ning[3], J. Maselko[3,*] Temporal and Spatial Organization of Chemical and Hydrodynamic Processes. The system Pb^{2+} - Chlorite - Thiourea Accepted J. Phys. Chem. A, March 2008

A. Baker, A. Toth, D. Horvath, J. Walkush, A. Ali, W. Morgan, A. Kukovecz, J. Pantaleone, J. Maselko . Precipitation Pattern Formation in the Copper(II) Oxalate System with Gravity Flow and Axial Symmetry *J. Phys. Chem. A*, **2009**, *113* (29), pp 8243–8248

J. Pantaleone, A. Toth. D. Horvath, L. RoseFigur, J. Maselko, Pressure oscillations in Chemical Garden, Phys. Rev. E 79,056221 2009

A. Toth, D. Horvath, A. Kukovecz, A. Baker, S. Ali, J. Maselko " Control of precipitation patterns formation in system Copper – Oxalate. Journal of Systems Chemistry 2012, **3**:4 doi:10.1186/1759-2208-3-4.