# The Silicate Garden

*"A water [solution] into which when any metal is put, it begins to grow within twenty four hours time in the form of plants and trees, each metal according to its inmost colour and property, which metal-line vegetations are called philosophical trees, both pleasant to the eye and of good use."*

Johan Glauber, *Furni Novi Philosophici* (1647)

*"To wit: an annunciation. I am to grow osmotic vegetation."*

Thomas Mann, *Dr. Faustus* (1947)

The Silicate Garden project is exploring the artistic potential of a specific type of chemical reaction that has captured the imagination of many across the centuries. The process is similar to crystallization, but in contrast to ultra-orderly crystals, this is "a self-organizing non-equilibrium process that creates complex structures."[1] These colorful structures have a remarkably organic appearance, hence the "garden" name.

Around the turn of the 20th century, these processes were thought to be able to give insight into the origin of life. This notion went into decline with the rise of genetics. Interest in the potential of relating these processes to artificial life has recently been revived under the term "chemobrionics."

**Metal salts**

A metal salt is formed when the hydrogen atoms of an acid (e.g., sulfuric, nitric, or hydrochloric) are replaced by a metal atom. For example, metallic copper (Cu) + sulfuric acid (H2S04) -> copper sulfate (CuSO4).

The metals used in this project are iron, copper, cobalt, zinc, nickel, and manganese (the cations). The salts may be sulfates, nitrates, or chlorides (the anions).

**Form**

The metal salts are added to an aqueous sodium silicate solution (sodium cation and silicate anion). The salts used are water soluble, so they dissolve into a metal cation and its associated anion. The metal cation bonds preferentially with the silicate anion to form an insoluble metal silicate.

The metal silicate forms a semi-permeable membrane in the form of an irregular bubble. Osmotic pressure inside the bubble increases as silicate anions flow across the membrane to replace the anions incorporated into the membrane. The bubble expands until it breaks and the process begins again. See right for a more detailed explanation.

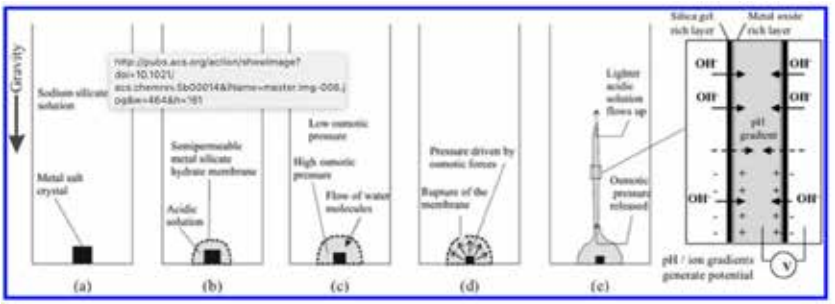
1. Laura M. Barge et al, "From Chemical Gardens to Chemobrionics" *Chemical Reviews*, July 2015

**Color**

Each metal salt used creates a distinctive color that is inherent in the atomic structure of its metal component. The atoms of these metals have partially-filled inner orbitals. The electrons in those orbitals are excited by energy in the visible spectrum, resulting in the coloration. If the wavelength produced is not in the visible spectrum, the color is white.

**Chemicals used in this project:**

Iron chloride - thick, twisty, orange-brown
Iron sulfate - very thin, spiky, dark color
Copper chloride - medium thick, columnar, light green
Copper sulfate - thin or none, dark blue-green
Cobalt nitrate - thin, twisty, dark purple
Manganese chloride - variable, light pink
Zinc sulfate - very thin, white
Nickel nitrate - green




Mechanism of growth of a classical chemical-garden structure from a metal-salt seed placed in sodium silicate solution. (a) Setup at the start of the reaction. (b) Membrane formation between acidic and basic solutions. (c) Osmotic pressure is higher within the membrane than outside it, so the membrane expands. (d) Under osmotic forces, the membrane ruptures. (e) A tube forms. Hydroxide ($OH^-$) is preferentially drawn into the interior of the membrane. The ionic and pH gradients across the membrane give rise to a membrane potential, as there is a difference in charge between the inner and outer solutions.[1]

*...certain incredible and eerie natural products that Adrian's father managed to breed from some bizarre culture, and which he like wise permitted us to observe. I will never forget the sight. The crystallization vessel in which this transpired was filled to three-quarters with a slightly mucilaginous liquid, diluted sodium silicate to be precise, and from the sandy bottom up rose a grotesque miniature landscape of different colored growths...*

*It turned out that these growths were of purely inorganic origin and arose with the aid of chemicals that came from Blessed Messengers pharmacy. Before pouring in the sodium silicate solution, Jonathan had sown the sand on the bottom of the vessel with various crystals with, if I am not mistaken, potassium dichromate and copper sulfate; and as the result of a physical process called "osmotic pressure," these seeds had produced their pitiable crop, for which their custodian immediately tried all the harder to solicit our sympathy. ..."Even though they're dead," Jonathan said, and tears came to his eyes-whereas Adrian, as I could well see, was shaking with suppressed laughter.*

*For my part I leave it to the reader whether such things deserve laughter or tears. I have only this to say: Phantasms of this sort are exclusively the concern of nature, and in particular of nature when she is willfully tempted by man. In the worthy realm of the humanities one is safe from all such spooks.*

Thomas Mann, *Dr. Faustus* (1947)

The Silicate Garden is a production of the Experimental Museum, located at Experiment in Portland, Oregon. The museum is a work in progress, sponsored by Zymoglyphic Museum.

For details, see zymoglyphic.org/about/experiment.html

If you want to try this yourself, you can start with the widely available "Magic Rocks" product. A more sophisticated kit is available from Innovating Science as "The Silicate Garden Chemical Demonstration Kit."