BRIDGES
Mathematical Connections
in Art, Music, and Science

Experiential Morphology
The Generative Dynamics of Form and Structure , Part II*

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"We have been trained to think of patterns, with the exemption of those in music, as fixed affairs. It is easier and lazier that way but, of course, all nonsense. In truth, the right way to begin to think about the pattern which connects is to think of it as primarily (whatever that means) a dance of interacting parts and only pegged down by various sorts of physical limits and by those limits which organisms characteristically impose."

Gregory Bateson, *Mind and Nature*

"We have had so much to do with the study of Form that pattern has been well-nigh left out of the account, although it is part of the same story. Like any other aspect of form, pattern is correlated with growth, and even determined by it."

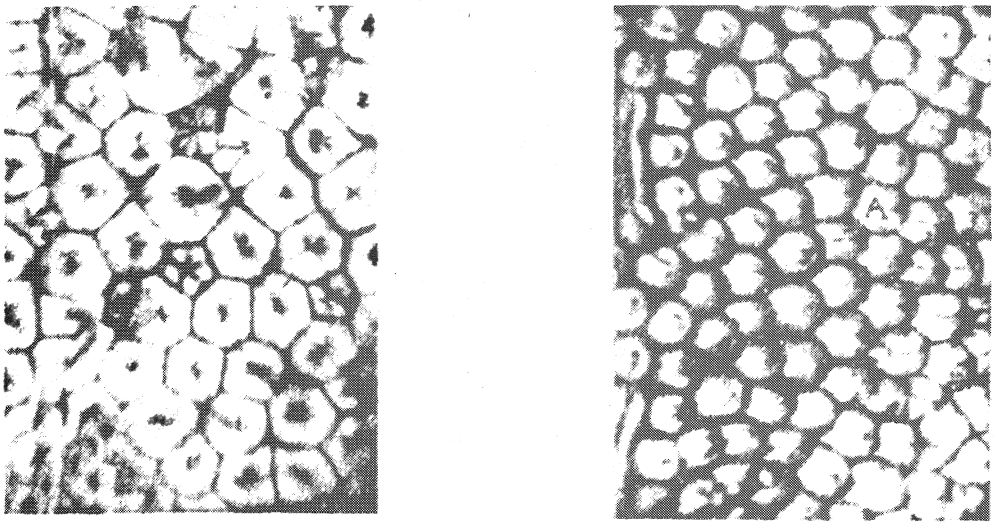
"Morphology is not only a study of material things and the forms of material things, but has its dynamical aspect, under which we deal with the interpretation, in terms of force, of the operations of Energy."

D'Arcy Wentworth Thompson, *On Growth and Form*

The "*Phenomenological Garden*" project is an architectural work-in-progress that is systematically exploring the morphological and integrative potential of fundamental processes existing throughout the natural environment. As part of the overall objectives of this project and the Forms Studies Unit at Carleton University's School of Architecture, students in the *Crossings* workshop have also carried out this exploration through projects that incorporate hands-on procedures derived from the research. These projects inherently allow for an intuitive learning process to occur through the nature of the materials and processes involved in the exploration.

Fundamental processes lurking within natural phenomena inherently generate regulatory systems and patterns that correlate with the rich diversity found throughout Nature. These fertile processes inherently involve elemental geometric relationships that dynamically evolve into integrative systems with startling form and structure generating capabilities. Modern computer visualization and analysing techniques are providing us with deeper insights into the ways the "*operations of Energy,*" referred to by D'Arcy Thompson above, can interweave into dynamic cellular systems and structures that often recall the patterns and motifs found throughout the natural and man-made environment. When the generative potential and interrelated cellular patterns of these systems are analyzed, they can yield more comprehensive insights into emergent complex behaviour and morphology. The intrinsic nature of these *process-patterns* reveals highly coordinated cellular relationships that are simultaneously stable and highly dynamic. Self-organization results from the resolution of the dynamic interactions. The "Bénard cells" shown in Figure 1 is a classic example of self- organization resulting from the flow of heat through a liquid, gas or smoke, as shown in the Figure. At a certain threshold, the heat flow suddenly reorganizes the liquid or gas into cellular convection currents. In

this critical state, the dynamic cellular pattern is highly sensitive to any disturbance and will re-organize itself as it resolves the instability resulting from any fluctuation (see Fig. 1 B). The overall toroidal form of each cell (hexagonal under ideal conditions) is stationary and stable while, simultaneously, the smoke dynamically circulates throughout the form.



A *B*

Figure 1: *Bénard Cells, pattern of cells generated with a thin layer of smoke between a hot and cold surface.* ***A****: Field of "rolling" torus cells: smoke rolls within each individual toroidal form,* ***B****: Cells are "sheared" by sliding one surface over the other from left to right. From* On Growth and Form*, by D'Arcy Thompson.*

Complex networks, such as "Benard cells," are fluently encoded patterns containing *information* and are themselves dynamic *processes-in-formation*. The probing of such event-filled "tapestries" and their associated cells can reveal new insights into the nature of the *reciprocal relationship* that exists between matter, developmental processes, growth and form. Through systematic analysis of the dynamic potential of basic geometric relationships, a series of flexible cellular units and hands-on experiential procedures have been developed that inherently allow for the intuitive discovery of the interrelationships between form, structure, and generative process. The cells consist of bamboo dowels that are joined together with a flexible joint (rubber bands), thus allowing for a high degree of malleability. The form generating potential of these cellular units is explored by joining (or weaving) them together into membranes or fabrics. The flexibility of the joints and their three-dimensional relationships, both within an individual cell and throughout the cellular fabrics or membranes, generates a wealth of forms and structures through the emergent transformative and organizing properties of the integrated assembly. How one explores and segments the fabric, determines the forms and structures that can be discovered and developed. The experience is that of a process whereby one feels, follows, flows with, and guides the versatile form generating properties of the dynamic relationships. The following figures show some of the forms, structures and installations produced through this process. As part of the evolving "*Phenomenological Garden*," the work seeks to explore how complex structures are generated from initially random processes that evolve into morphologically rich collective relationships.

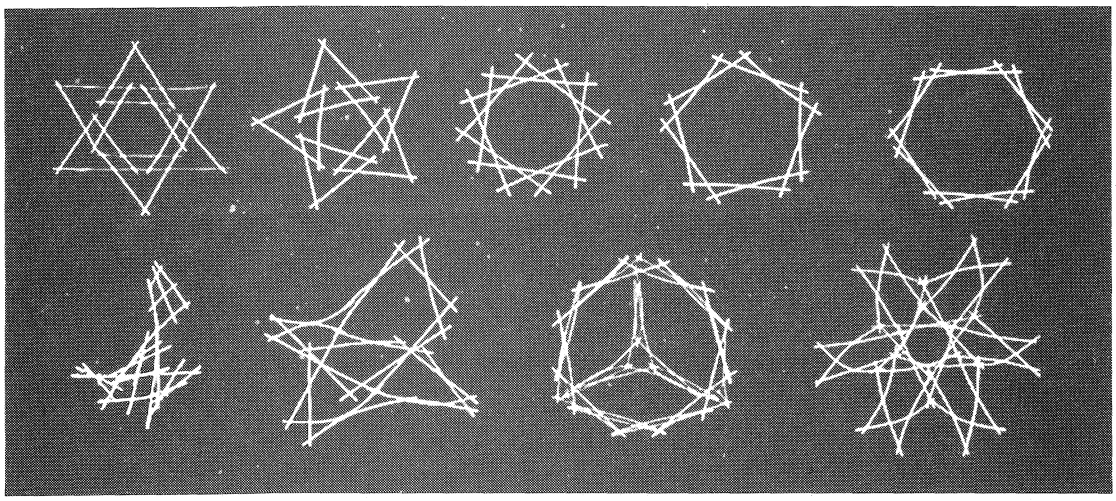


Figure 2: ©*Crossings Workshop,* Suspended Animation Series*: Cells and cellular arrangements: 12" bamboo dowels joined together with rubber bands. These initial cells and cellular arrangements are woven together into flexible membranes or fabrics. Different cut-out patterns of the membranes will generate different forms and structures through the inherent flexibility of the integrated assembly.*

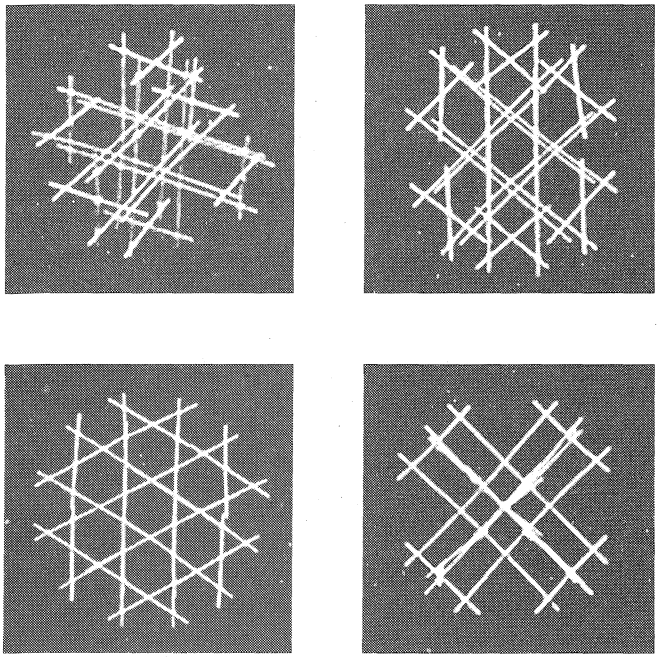


Figure 3: ©*Crossings Workshop,* Suspended Animation Series*: views of "X, Y & Z Coordinates" Cellular Unit: three intersecting planes at right angles to each other. Lower right: clearly shows one of the planes with the central diagonal edges of the other two. Upper right and lower left: show views through the four diagonals of the cubic assembly. The fabrications shows in Figure 6 are all constructed with this cellular unit.*

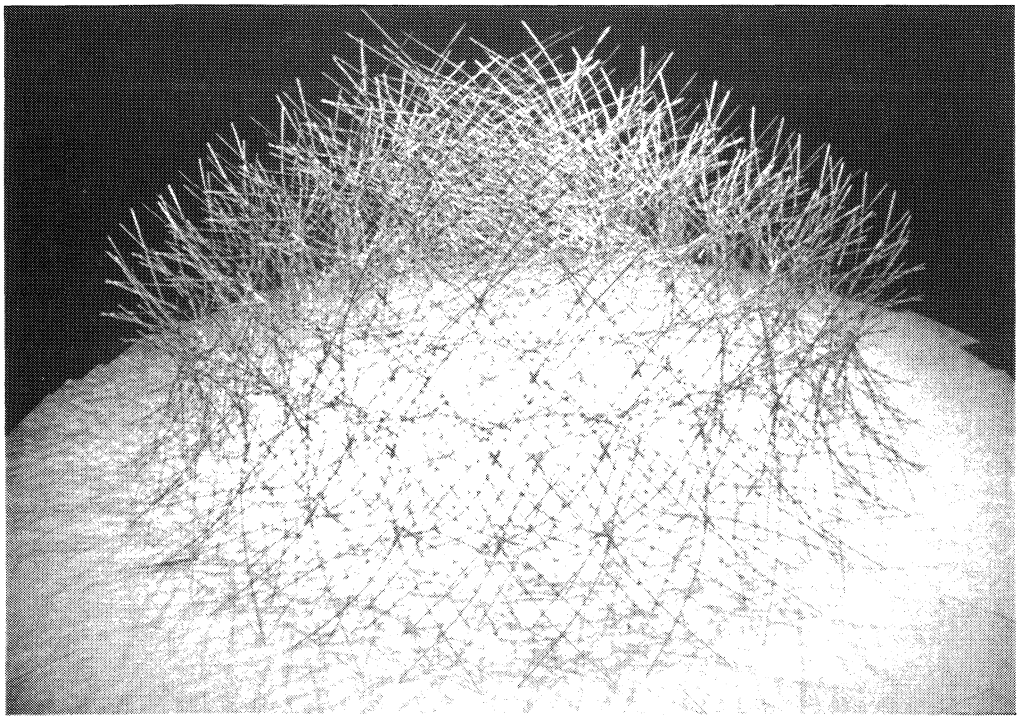


Figure 4: ©*Manuel A. Báez,* Suspended Animation: Coiled serpent, *Network Gallery, Cranbrook Academy of Art, 1997. Fabrication using square cellular units (shown in lower left corner of Figure 2), 12" and 6" bamboo dowels joined together with rubber bands.*

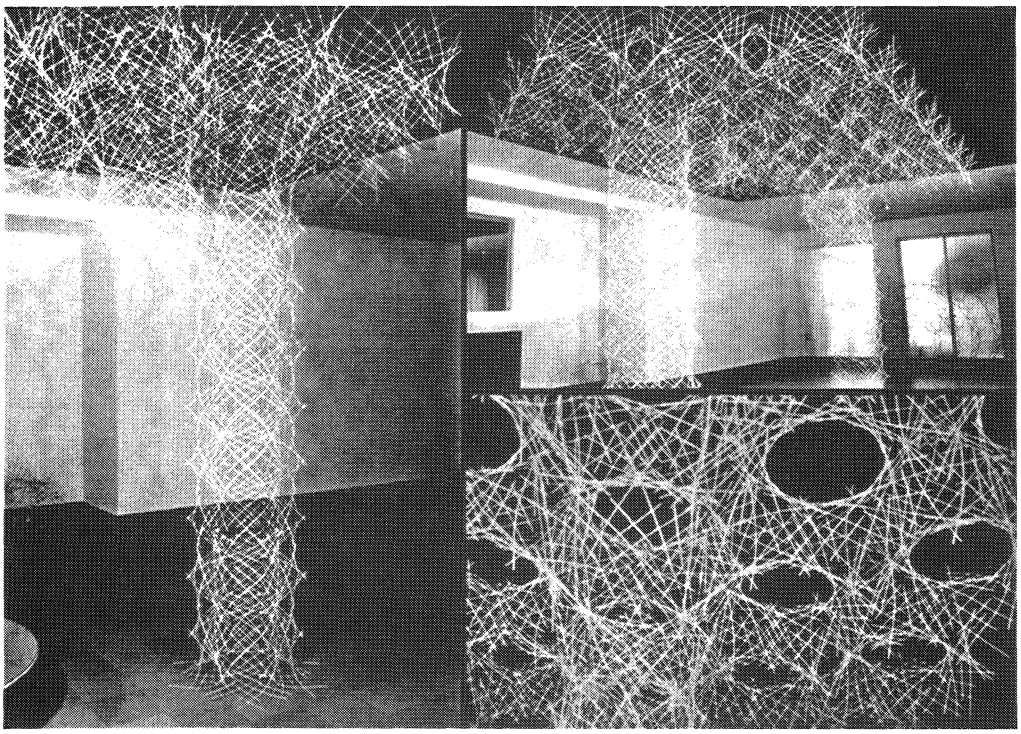


Figure 5: ©*Manuel A. Báez,* Phenomenological Garden *Installation, Cranbrook Academy of Art, Bamboo dowels & rubber bands, 1998. Two columns are transformed into an intricately patterned ceiling structure. Emergent patterns are revealed as one walks around the installation or, as shown in the lower right, as one looks into the mirrored central table that is partially shown on the left. Fabrications with square cellular units shown in lower left-hand corner of Figure 2.*

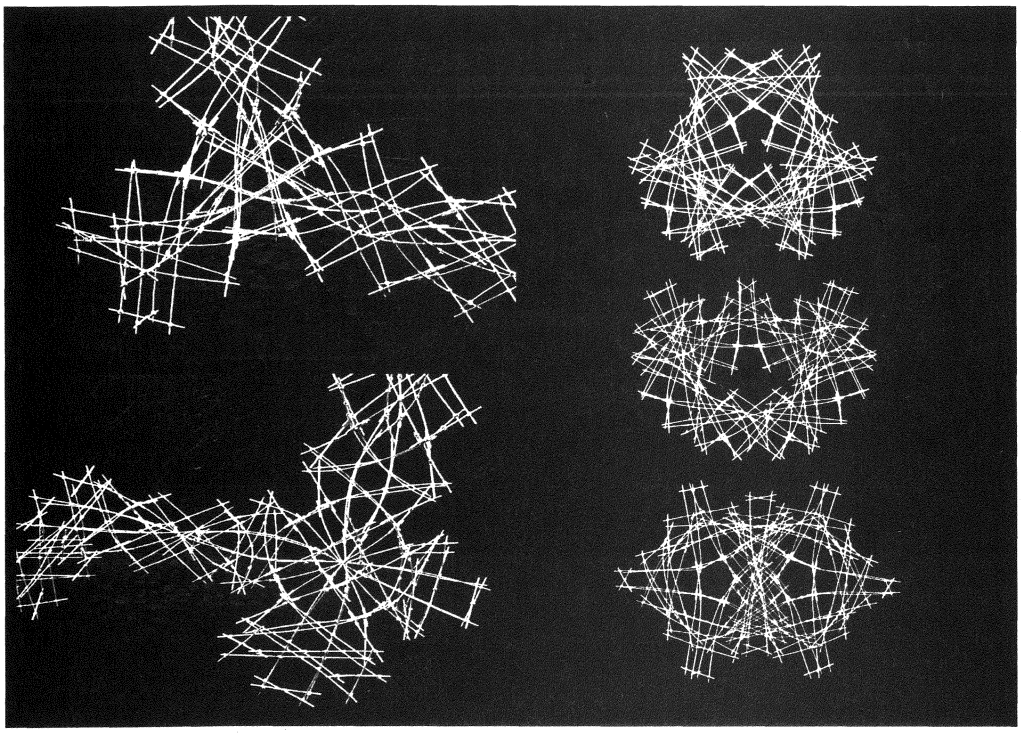


Figure 6: ©*Crossings Workshop,* Suspended Animation Series*: Cellular Forms Studies with cubic units as shown in Figure 3, 2003. More information on the properties of this particular unit can be found in the Bridges 2003 conference proceedings.*

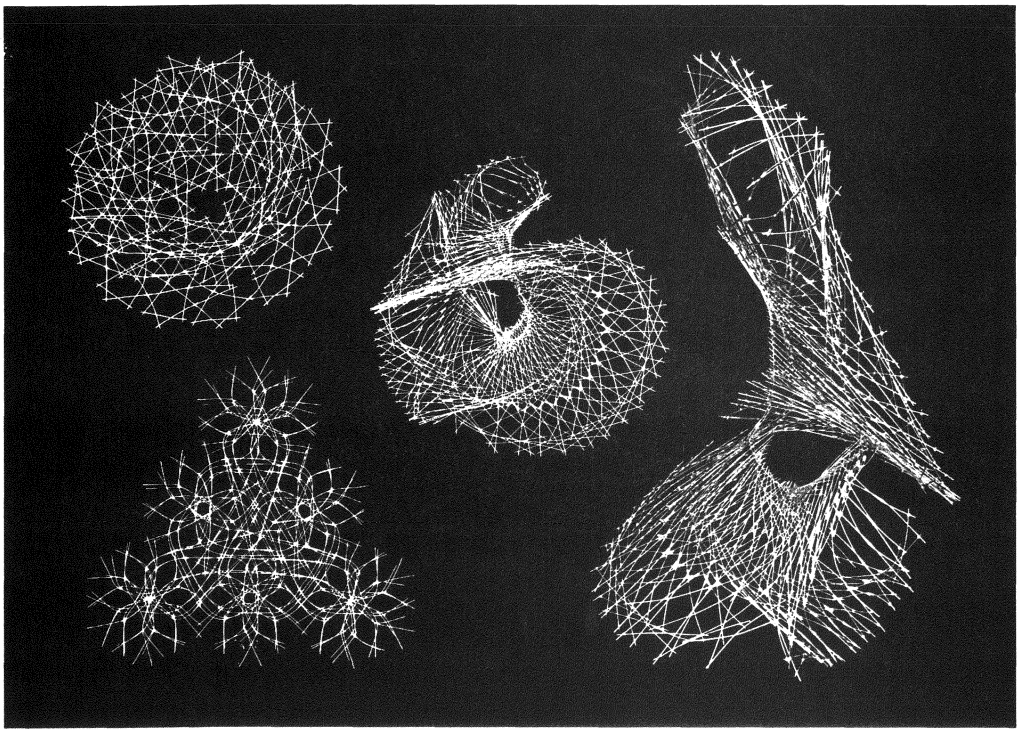


Figure 7: ©*Crossings Workshop,* Suspended Animation Series*: Cellular Forms Studies, Bamboo dowels & rubber bands, 2003-4. Works by Ti Truesdale, Diana Park, and Karam Georges. The two right side structures and upper left: using heptagonal cellular units; lower left; using square cellular units.*

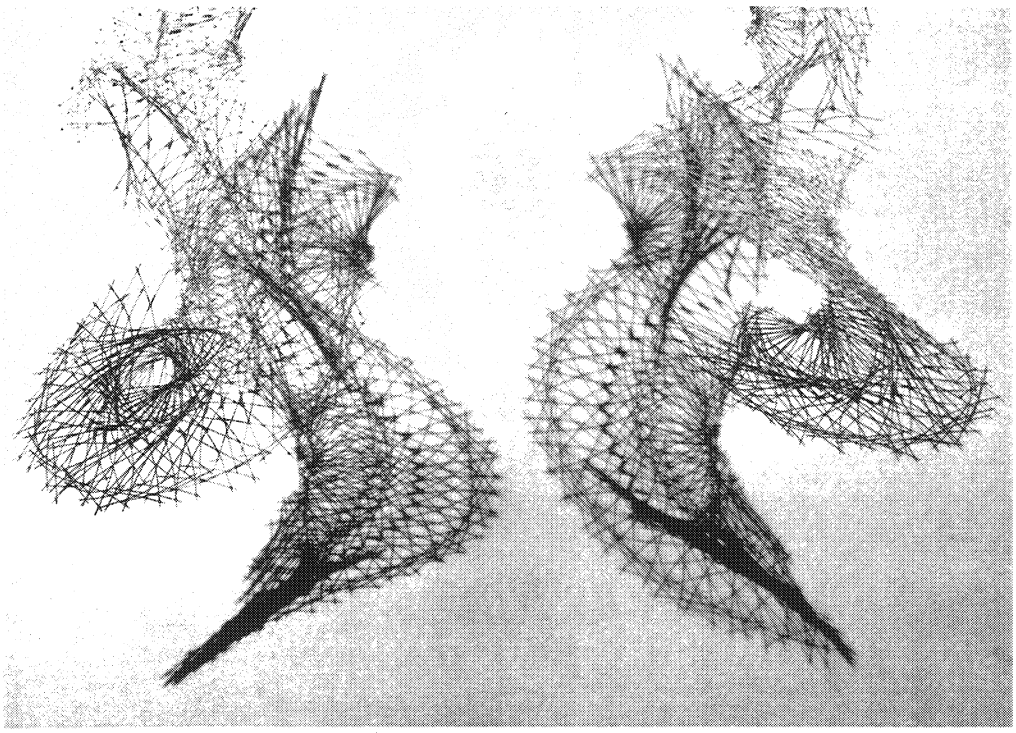


Figure 8: ©*Crossings Workshop,* Suspended Animation Series*: Cellular Forms Studies using heptagonal units and shadow "castings," 2002. Work by Diana Park.*

***Note**: Part I of this paper is included in the 2002 Bridges Conference Proceedings and a more detailed paper on the cellular form studies shown in Figures 3 and 6 is included in the 2003 ISAMA/Bridges Conference Proceedings.