Developmental Morphology: X, Y, & Z Coordination as a Dynamic and Generative Cellular Process

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Abstract

The architectural work-in-progress titled the *Phenomenological Garden* has been exploring the morphological and integrative potential of the cellular units generated by fundamental processes within natural phenomena. 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 been carrying out these explorations through projects that incorporate hands-on procedures derived from the research. The inherent properties of the cellular units, along with the nature of the materials and processes involved in these projects, allow for a generative and intuitive learning process to occur. Previously, the generative dynamics of two-dimensional cellular units have been explored. This paper presents the work that has emerged from the exploration of the X, Y and Z coordinate system as a fundamentally dynamic relationship within a generative cellular process.

1. Introduction

"We are living in a world where transformation of particles is observed all the time. We no longer have a kind of statistical background with permanent entities floating around. We see that irreversible processes exist even at the most basic level which is accessible to us. Therefore it becomes important to develop new mathematical tools, and to see how to make the transition from the simplified models, corresponding to a few degrees of freedom, which we have traditionally studied in classical dynamics or in quantum dynamics, to the new situations involving many interacting degrees of freedom."

Ilya Prigogine [1]

"In this brief account of coordinate transformations and of their morphological utility [The Theory of Transformations, or The Comparison of Related Forms] *I have dealt with plane coordinates only, and have made no mention of the less elementary subject of coordinates in three-dimensional space . . . And that it would be advantageous to do so goes without saying, for it is the shape of the solid object, not that of the mere drawing of the object, that we want to understand; . . . But this extended theme I have not attempted to pursue, and it must be left to other times, and to other hands."*

D'Arcy Wentworth Thompson [2]

There are systems and patterns generated by fundamental processes existing throughout the natural environment. These fertile, self-organizing and regulatory processes inherently exist within and generate this rich realm of natural phenomena. They are also simultaneously composed of and generate elemental geometric relationships that gradually evolve into versatile integrative systems with startling form and structure generating capabilities. When the versatility and generative potential of these systems and their interrelated cellular patterns are systematically analyzed, they can yield new insights into the emergence of complex morphological structure and form. The intrinsic nature of the patterns generated by these dynamic processes reveals that they are cellular configurations of highly ordered relationships. Through these apparently static and stable patterns flow the highly dynamic undulations of energy. These emergent complex networks are fluently encoded patterns of potentiality offering a multitude of possible or alternative "readings." The cellular units comprising these patterned networks innately contain the intrinsic attributes of the versatile processes that generated them. We are inextricably part of and surrounded by this rich and dynamic matrix of natural phenomena. The probing of the inherent nature of this generative matrix can reveal new insights into the nature of the *reciprocal relationship* between matter, developmental processes, growth and form. Rich and exciting educational methodologies are offered through new procedures and techniques that would inherently allow for intuitive learning through self-discovery. The *Phenomenological Garden* project is a work-in-progress and in-process that has been inspired by these insights and the working procedures that they can reveal regarding nature's developmental processes. It seeks to explore the form and structure generating potential of these dynamic processes along with their elemental components, emergent integrative properties and pattern generating capabilities.

Systematically, the dynamic properties of basic geometric relationships have been analysed, leading to the development of a series of flexible cellular units and hands-on procedures that inherently allow for the intuitive discovery of the interrelationships between form, structure, and generative process. Typically, the cellular units are constructed using bamboo dowels that are joined together with rubber bands. By joining these highly flexible units together into three-dimensional configurations, the form generating capabilities of both the individual cells and the cellular assemblies can be easily explored. The flexibility of the joints and their complex three-dimensional relationships, generate a wealth of forms and structures through the emergent, transformative and organizing properties of the integrated assembly. The dynamic properties of initially two-dimensional cellular units have been explored (see the paper: *Experiential Morphology: The Generative Dynamics of Form and Structure*, 2002 Bridges Conference Proceedings, p. 315-318). These have been hands-on dynamic explorations of what were primarily graphic, two-dimensional and static explorations by D'Arcy Thompson [2] through his *Theory of Transformations or The Comparison of Related Forms* (see Fig. 1).

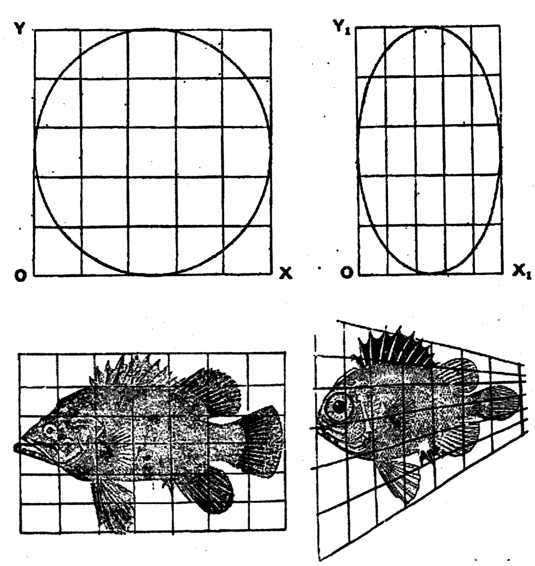


Figure 1: *D'Arcy Thompson, grid or coordinate transformations of a geometric figure and a graphic depiction of a biological form* [2].

As recommended by Thompson in the introductory quote above, three-dimensional coordinate transformations have been explored through investigations of the generative dynamics of complex assemblies. The following is a presentation of some of the forms and structures generated from the emergent properties of several intrinsic combinations of a cellular unit that is a dynamic three-dimensional assembly of the X, Y and Z system of co-ordination.

2. X, Y and Z Co-ordination: The Intermingling

Figure 2 shows four views of the cellular unit constructed with 12" and 5" bamboo dowels that are joined together with rubber bands. The unit is composed of three surfaces (or planes) at right angles to each other with each surface being defined by four 12" dowels assembled into a grid of two pairs at right angle to each other and four 5" dowels, one at each end of the 12" pairs (Figure 2 D). The three surfaces have a high degree of transformability due to the flexibility of the joints and each surface defines one of the X, Y and Z coordinate directions in three-dimensional space. Each surface can fully collapse along the two orthogonal diagonals of the assembled grid. They can also be warped into a transformable, collapsible and highly flexible hyperbolic paraboloid. Three-dimensionally, this cubic cellular unit (or module) is composed of "*interacting degrees of freedom*" through the combination of flexible joints (a total of 42). From another perspective, this complex intermingling is also the interactions of the three flexible hyperbolic paraboloids within the three-dimensional assembly. Figures 3 and 4 show several configurations that can be generated from this dynamic interplay.

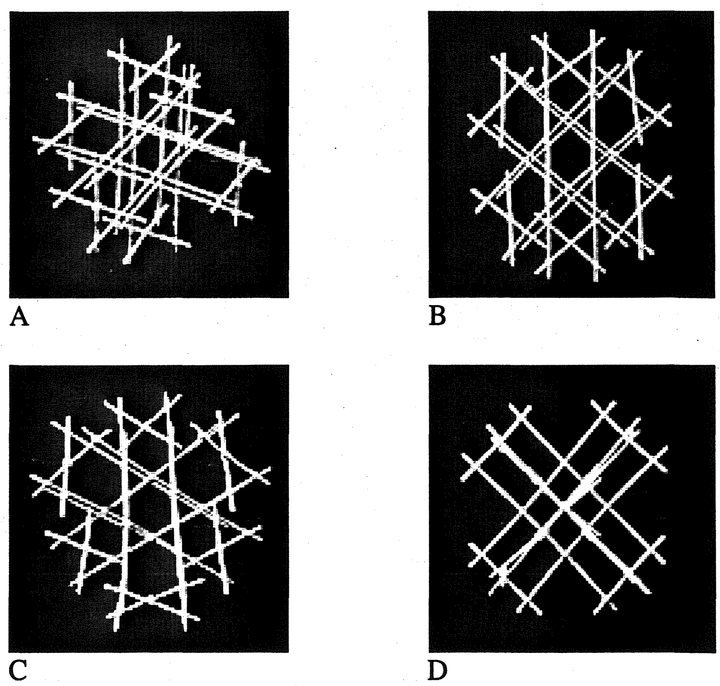
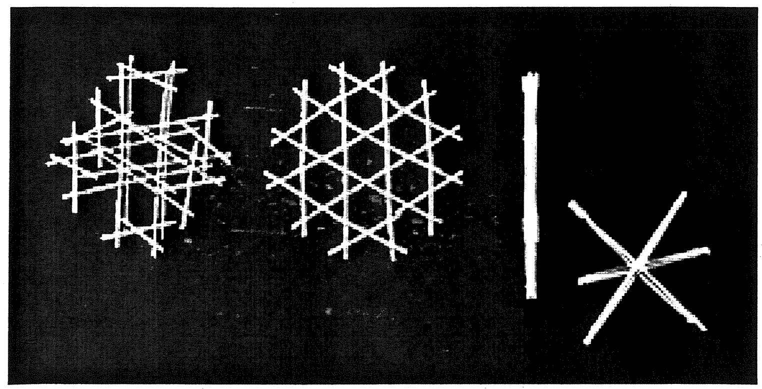
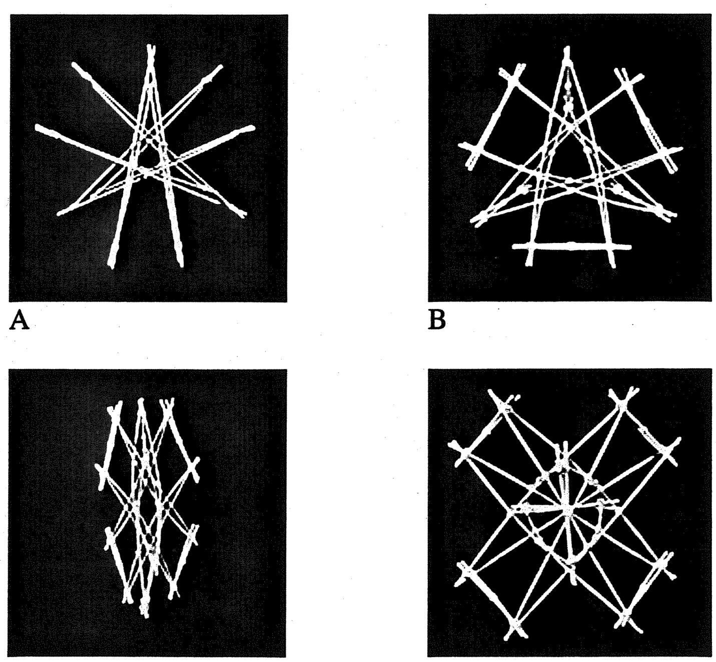


Figure 2: *Views of the X, Y & Z Cellular Unit: 12" and 5" bamboo dowels and rubber bands. Three planes at right angles to each other:* ***D*** *clearly shows one of the planes with the central diagonal edges of the other two;* ***B*** *&* ***C*** *show views through the four diagonals of the cubic assembly.*



A B C D

Figure 3*: The Cellular Unit and several of its basic transformations.* ***A****: The Cellular Unit.* ***B****: Flattened assembly along one of the four diagonals of the cubic assembly.* ***C****: Collapsed assembly centered around one of the four diagonals.* ***D****: Collapsed X, Y and Z axes with 5" dowels removed (see Fig. 5).*



A B C D

Figure 4: *Different transformations of the Cellular Unit. In A the 5" dowels have been removed. Each one of these configurations becomes the "modified" cellular unit that is then assembled together.*

Figures 4 and 5 show several of the transformations that can be generated from the cellular unit through a systematic hands-on investigation of its dynamic properties. In the *Crossings* Workshop, students have been exploring this cellular unit along with the forms, structures and dynamic properties that emerge when several of these units are combined through very intrinsic assembling procedures. The numerous possible ways of assembling lead to unexpected overall patterns and dynamic arrangements that generate new and diverse developmental directions for the assembling process.

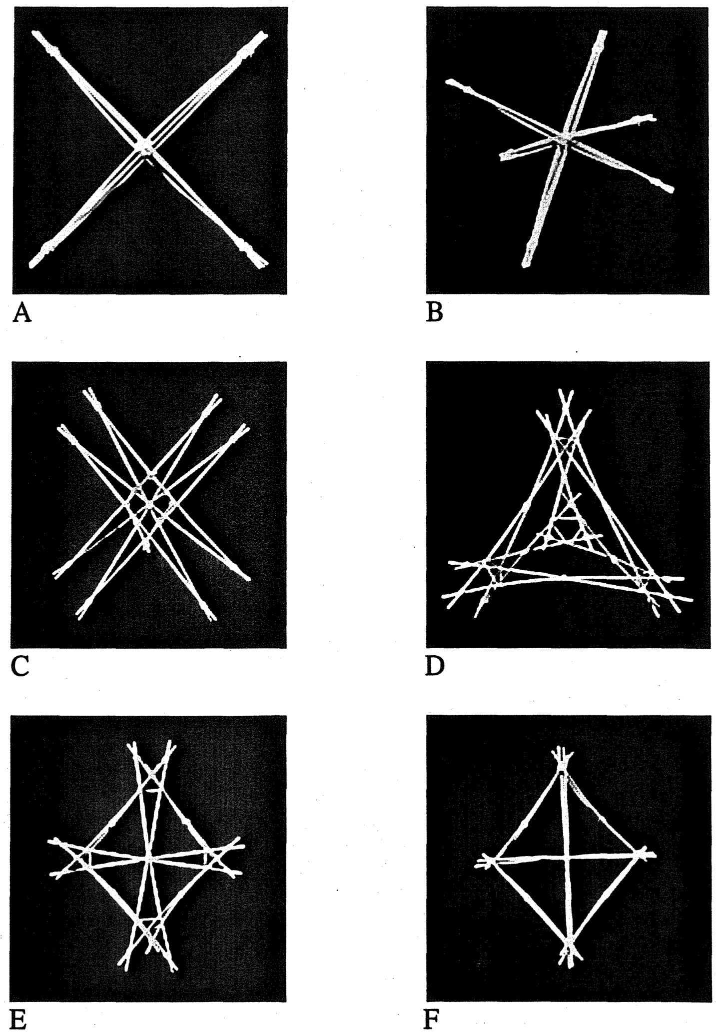
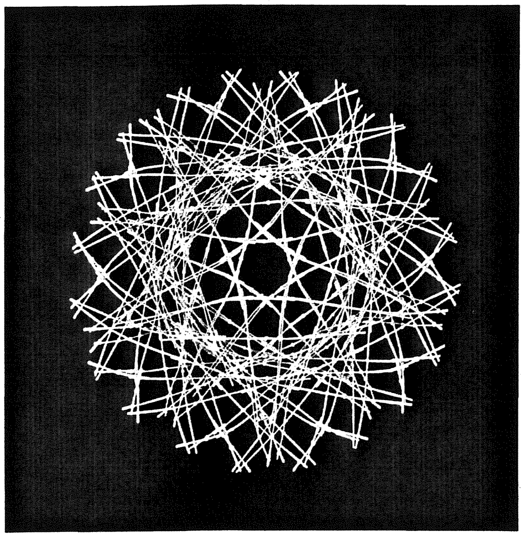
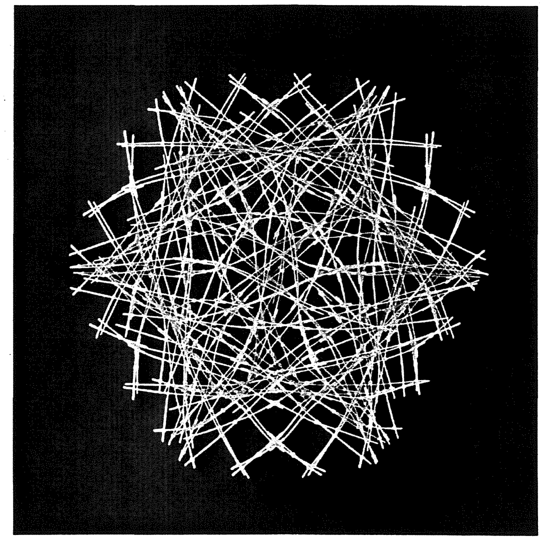


Figure 5: *Different stages of a cellular unit that can completely collapse into the X, Y and Z axes (**A & B**) and gradually expand into a tetrahedron (**C, D, E and F**).*

Figures 6, 7 and 8 show several forms and structures that can emerge as the assembling process gradually evolves into more complex configurations. Figures 6 A & B show two axial views of the same construction. This particular assembling process generated a dodecahedron that was not preconceived nor initially anticipated. Cellular units (as shown in Figure 3 A) were assembled together using their inherent properties as the guiding principles. Within the resulting three-dimensionally dynamic pattern of the form one can discern the complex interweaving of the rich geometric properties of the dodecahedron: cubes, tetrahedrons, hexagons, pentagons and golden rectangles (to name a few) in a reciprocally complex relationship. Several of these shapes can be discerned in the two views provided. Figure 7 A is another construction generated through the same process as in Figure 6 and also reveals the same level of complex multilayering of forms. Figure 7 B shows a construction that incorporates the cellular unit shown in 4 B. The different modifications to the original unit in Figure 2 lead to the emergence of totally different complex patterns and dynamic properties. In 7 B, the X, Y and Z axes of the initial cellular unit are equally prevalent at this level of evolving complexity.

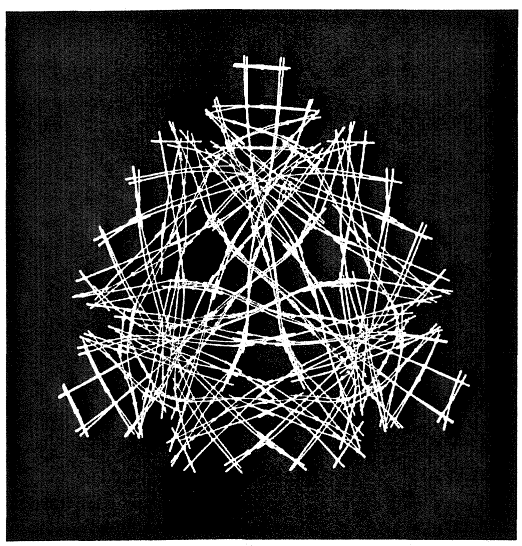


A

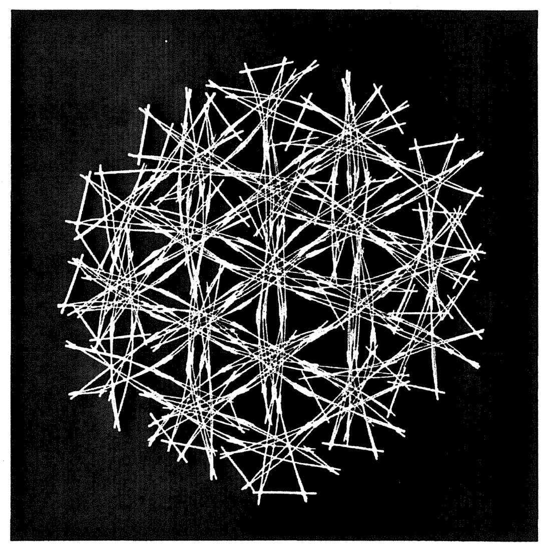


B

Figure 6: *Two views of the same construction, by M. Báez, using the cellular unit shown in Fig. 3. The construction is a dodecahedron that emerged from the assembling process. Throughout the structure and the generated patterns one can discern the squares, pentagons, triangles, hexagons, cubes and tetrahedrons that are intrinsically embedded within the dodecahedron.*



A



B

Figure 7: *Cellular Constructions. A: By M. Báez, constructed with the same unit as in Figure 6 and exhibits the same properties. B: By Sarah Amirault, constructed using the unit shown in Fig. 4 B. Different patterns are revealed throughout these constructions. The X, Y and Z axes can be clearly seen in the overall pattern in B.*

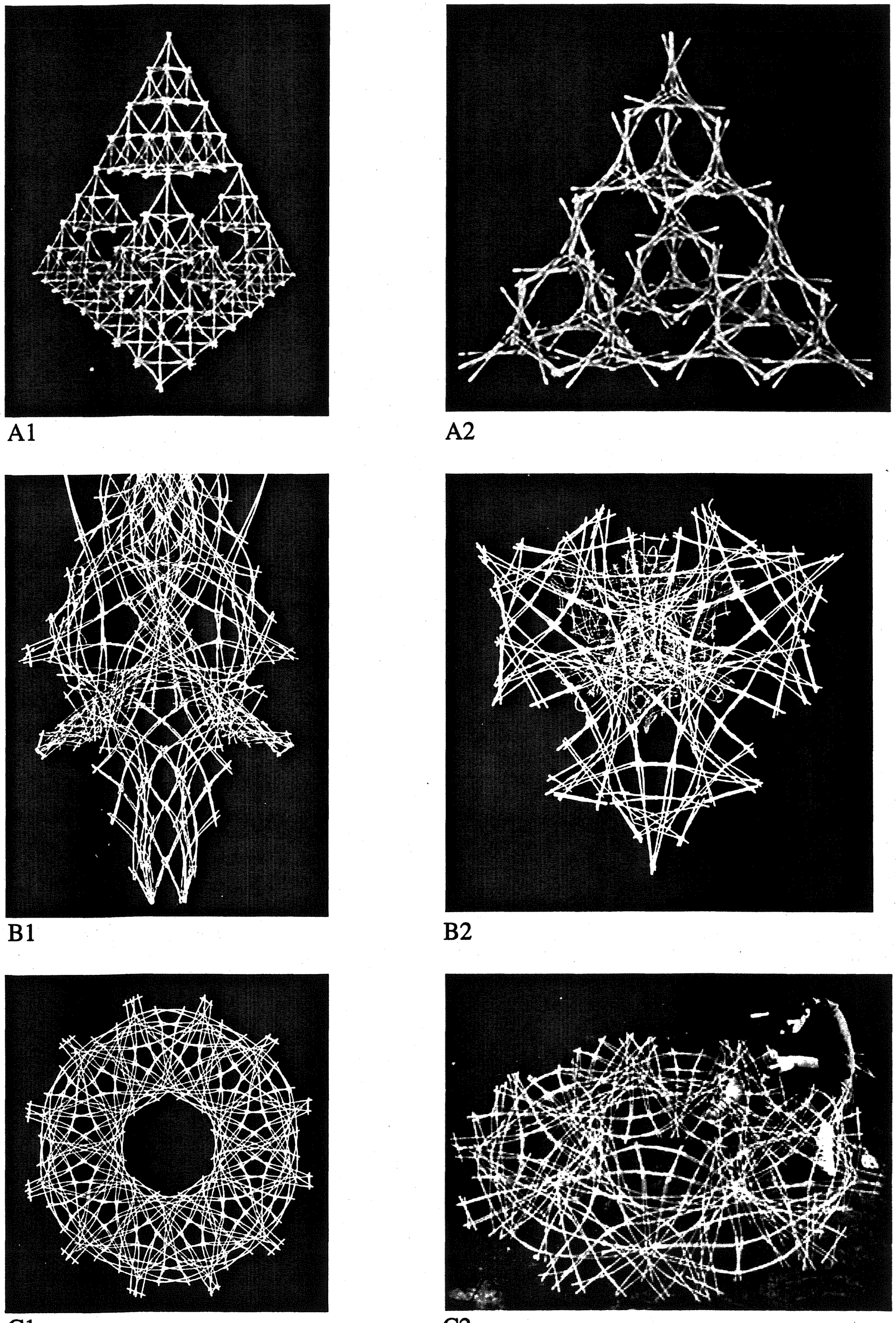


Figure 8: *Cellular Constructions.* ***A1** & **A2**, by Dan Levin and Michael Lam, constructed with the unit in Fig. 5: **A1**, with the units fully expanded and **A2**, with the units almost fully collapsed. **B1** & **B2**, by Michael Putman, Patrick Bisson and Rheal Labelle, with the unit in Fig. 3. **C1** & **C2**, by Ana Lukas, with the unit in Fig. 3.*

Figure 8 shows three constructions that have been developed to a more complex level than the ones previously shown. A1 and A2 show two constructions made with the cellular unit shown in Figure 5. The transformability of this cellular unit generates very different overall complexity within the larger assemblies. A1 shows a pyramidal structure with the cellular units fully expanded (as in Figure 5F). Four smaller pyramidal structures make-up this overall structure. One of those is shown in A2 with the cellular units in an intermediate stage (between Figure 5C-D). An interesting change in the overall structure and pattern occurs through the gradual transition from fully collapsed to fully expanded. The interrelationships between the X, Y and Z axes, the cube and the tetrahedron are clearly seen through this transition (see Figure 5A-F). In Figure 8, B1 and B2 show the most complex construction that has been made with the cellular unit used in Figure 6. B2 shows the view from above through the main vertical axis of the elaborate assembly and B1 shows a partial side view. Here again, the elaborate pattern is ever changing throughout the structure. In Figure 8, C1 and C2 show a toroidal construction that was assembled with the same unit and procedures used in Figures 6 and 7A. The form shown in Figure 6B fits directly into the central opening of the form shown in Figure 8 C1. By comparing C1 and C2, in Figure 8, one can see the dynamic diversity within the elaborate pattern. Overall, the emergent patterns are at times reminiscent of the patterns generated by vibrations in liquids and in thin layers of fine powder. Throughout all of these constructions, dynamic patterns emerge with an ever-evolving intricate level of complexity. Paradoxically, within the integrative interactions of this complexity lurks the simplicity of cellular units.

Conclusion

"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 [3]

The rich diversity found throughout nature's processes challenges our creative imagination and common sense because of its reciprocally related combination of dynamic complexity and simple organizing principles. The work-in-progress presented here, along with the broader goals of the *Phenomenological Garden,* inherently address this fundamental paradox through multidisciplinary research and an integrative working process. Such an approach offers new possibilities and directions to the fields of morphology, architecture and other creative disciplines at a time when there is an increasing interest in the broad implications of our deeper understanding of Bateson's "*dance of interacting parts*" throughout the physical world.

References

[1] Paul Buckley and F. David Peat (editors), *Glimpsing Reality: Ideas in Physics and the Link to Biology*, University of Toronto Press, p. 99. 1996.

[2] D'Arcy Wentworth Thompson, *On Growth and Form.* Complete Revised Edition: Dover, p. 1087. 1992. Chapter XVII covers The Theory of Transformations, or The Comparison of Related Forms (P.1026-1095).

[3] Gregory Bateson, *Mind and Nature*, Bantam Books, p. 13-14. 1980