Material/matter/mater: the fundamental integrating principles

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Abstract

Through the ever-increasing sophistication of modern computer visualization and analysing techniques, a greater and more insightful comprehension has emerged regarding the fertile, self-organizing and regulatory processes lurking within natural phenomena. Throughout these systems, the complex behaviour and emergent properties of matter evolve from initially simple starting conditions that eventually generate unpredictable behaviour. These developments directly relate to the radical re-conceptualisation that occurred in the first decades of the twentieth century regarding the nature of matter, its organization and its constituent parts. They also offer new possibilities towards achieving the integrative design strategies aspired to by key central figures and institutions in the history of modern architecture. The comprehensive design goals of the formative period of modern architecture and design were inspired by a reverence towards nature’s integrative and adaptive capabilities. Insights derived from these developments have been incorporated into an interdisciplinary workshop, architecture studios, and into Materials, Principles and Methods of Construction courses. The educational procedures and techniques resulting from this research inherently allow for an intuitive learning process to occur while, simultaneously, introducing students to the rich potential of the working process, as well as the historical significance of the developments that inspired their conception.

Keywords: matter, materials, complexity, chaos, emergence, fractals, self-organization, morphology, natural phenomena, developmental processes.

1 Introduction

“Materials! What a resource! These materials are human-riches. They are Nature-gifts to the sensibilities that are, again, gifts of Nature.”
“Nature as I have used the word must be apprehended as the life-principle constructing and making appearances what they are, for what they are, and in what they are. Nature inheres in all as reality. Appearances take form and character in infinite variety to our vision because of the natural inner workings of this Nature-principle. The slightest change in a minor feature of that ‘Nature’ will work astounding changes of expression.

When the word Nature is understood and accepted in this sense, there is no longer any question of originality. It is natural to be ‘original’ for we are at the fountainhead of all forms whatsoever.”

Frank Lloyd Wright [1]

“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 [2]

Fundamental processes in nature inherently generate regulatory systems and sub-systems that correlate with the rich realm of natural phenomena and the innate nature of matter. Through modern computer visualization techniques we are acquiring greater insight into the inner workings and evolving properties of these processes. These developments are demonstrating the rich complexity and emergent properties of these process-systems while simultaneously revealing the simplicity of their origins. Extremely simple initial rules and procedures inevitably evolve and develop into incredibly unpredictable and non-linear complex behaviour at higher levels of organization. A greater comprehension is emerging regarding the fertile, self-organizing and regulatory procedures lurking within the nature of matter, natural phenomena and materials. These dynamic processes are inherently composed of interweaving elemental relationships that evolve into highly integrative multi-levelled systems with startling form and structure generating capabilities. Intrinsically and paradoxically, they are also highly coordinated cellular relationships that are simultaneously stable, highly dynamic, self-organizing and fluently encoded with information. These developments fundamentally contradict the mechanistic worldview of classical Newtonian science that emerged in the seventeenth and eighteenth centuries. “Our vision of nature,” write the chemists Prigogine and Stengers, “is undergoing a radical change toward the multiple, the temporal, and the complex. For a long time a mechanistic worldview dominated western science. In this view the world appeared as a vast automaton. We now understand that we live in a pluralistic world.” [3].

These developments reinforce and expand upon the radical conceptual transformation that occurred in the early twentieth century regarding the nature of matter, its organization and its constituent parts. This new vision of nature offers us new strategies towards understanding the inner workings of nature’s processes and systems: a goal that was at the heart of the conceptual and philosophical aspirations of such leading architects in the formative period of the
modern movement in architecture and design as Antoni Gaudi, Louis Sullivan, Frank Lloyd Wright, Le Corbusier, and Buckminster Fuller.

2 The nature of matter

The new vision of nature that emerged in the early twentieth century re-conceptualised the very nature of matter at its most fundamental level. Basic elemental units of matter were revealed to consist of contradictory, yet intrinsic, characteristics with far reaching implications beyond the field of science. The solid materiality and mechanistic vision of Newtonian science dominated the scientific conceptual imagination regarding all physical phenomena. Eventually, this idea was discarded when it was revealed that those solid material entities were composed of wavelike patterned networks of probabilities or potentialities. This contradictory nature of matter has been encountered throughout history whenever the nature of substance and form has been contemplated. This was the modern counterpart of the dreams of the natural philosophers of nearly 2,500 years ago. An understanding of the intrinsic nature of what constitutes a pattern would provide the necessary insights into a deeper understanding of the very nature of matter, natural phenomena and materials.

2.1 Critical sensitivity and self-organization

Intrinsically, the patterns and forms generated by natural processes consist of cellular assemblies of highly self-organized relationships. Through these apparently static assemblies flow the dynamic undulations and fluctuations of “the operations of Energy” referred to by D’Arcy Thompson. Self-organization results from the resolution of these 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, as shown in Fig. 1, smoke. 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. 1B).

The process-structures resulting from dynamic phenomena (or “far-from equilibrium” phenomena [3]) are critically sensitive to the generative conditions within which they evolve and exemplify essential and unanticipated characteristics of matter. Any slight change or fluctuations in these initial conditions can start a new evolutionary process that will drastically change the macroscopic behaviour of the system and, therefore, the evolving structure and form. This should be understood as evolving out of the kind of Nature referred to by Frank Lloyd Wright: “…the life-principle constructing and making appearances what they are, for what they are, and in what they are.” The critical sensitivity of these systems was also envisioned by Wright: “The slightest change,” he writes, “in a minor feature of that ‘Nature’ will work astounding changes of expression.” The gravitational and magnetic fields of the earth are two such pervasive conditions within which natural phenomena evolve.
2.2 Coherent entities

These critically sensitive process-patterns and systems generate a new coherence, a new process of inter-communication and inter-activity among its cellular units (or molecules). This kind of communication is the very essence of biological systems as exemplified by the complex coherence of the human body. A fundamental characteristic of complex biological systems is that there is permanence to the overall macro behaviour while, simultaneously, the constituent parts are continuously dying out and being replaced. The human body is one of these complex systems similar to ant colonies or beehives. Hundreds of different cell types make up the overall complexity of the body. Approximately 75 trillion of these cells are actively at work in our body. In a matter of seconds, thousands of these cells have died and billions have been completely replaced within a week. This high turnover rate does not affect our overall conscious awareness of a “permanent” body. Contained within each cell nucleus is the entire genome for an organism with individual cells reading only a small portion of that information. The interactive context within which the individual cell finds itself, will determine the tiny portion of information that it will read. Through this multi-cellular communication process, cells self-organize into more sophisticated structures. Cells can detect the overall state of their surroundings as well as any changes within that state such as gradient fluctuations. Through this process, cells eventually self-organize into complex collectives leading to more complicated and sophisticated interactions. Throughout this decentralized process, local interactions and communication leads to the emergence of coordinated collective behaviour at different levels or scales of interactivity.
2.3 Active matter

This dynamic and complex vision of Nature, as described by Prigogine and Stengers [3], also envisions the formation of dynamic states of matter with an embedded generative potential. Dissipative structures are such dynamic states of matter. They are maintained far-from-equilibrium by an overall flow of energy, which the system dissipates through its complex activity. The input of energy must be maintained in order to maintain the dynamic process-patterns of these critical states [5]. The spatial and time scale of these dissipative structures and their patterned-activity are related to the spatial and time scale of our own awareness: seconds, minutes, and hours. In contrast, the time and spatial scale of such equilibrium structures as crystals is directly related to the extremely high vibration frequency of the individual molecules.

Figure 2: Manuel A. Báez, *Phenomenological Garden* installation at Cranbrook Academy of Art for the Metaphoric Interweavings Symposium, Bloomfield Hills, Michigan, USA, 1998.

3 Generative material complexities

The emergent complex networks described above are fluently encoded process-patterns of potentiality offering a multitude of form and structure generating possibilities. When this generative potential is systematically analysed, it can yield more comprehensive insights into emergent complex morphology and associated material properties. These integrated elemental structures and materials inherently contain a record of their generative process. An
understanding and appreciation of our innate relationship with this phenomenon can be achieved through hands-on systematic investigations of these emergent properties. As an educator, I have incorporated the insights emerging from this research into several interdisciplinary courses where the form and structure generating potential of materials and process-patterns is being explored.

Figure 2 shows an installation of a project that was constructed from a cellular membrane made with bamboo dowels that are joined together with rubber bands. The project has been investigating the generative potential of a flexible orthogonal membrane constructed with a square cellular relationship of flexible joints. The generative potential of this very basic pattern is revealed when it is dynamically explored. Figure 3 shows a project that also explored an orthogonal grid by interlacing strips of wood into square cellular units that are then joined together. The forming potential is revealed as one actively interacts with the flexible material and dynamic pattern.

Figure 4 shows a project that has explored “tensegrity membranes” made with latex sheets and wooden compression members. By drawing basic patterns on the latex sheets and systematically inserting standard size wooden compression member throughout the pattern, several versatile structural forms were generated.

Figure 3: Materials and Pattern Explorations, basswood strips woven into a flexible orthogonal grid. Works by Sukie Leung, 2001.

The left side of figure 5 shows a structure that was made with strips of corrugated cardboard. The structure of the corrugated cardboard was analysed and modified by systematically scoring (cutting) its surfaces in several patterns.
Figure 4: Materials and Pattern Explorations, “tensegrity membrane”: latex sheet with 1/8 inch wooden dowels as compression members. Works by Chi Nguyen, 2001.

Again, the nature of the material, its structure and the dynamic potential of appropriate patterns were explored through the form generating possibilities. The right side of Figure 5 shows two views of a “seashell” like form that emerged when a continuous strip of wood was coiled on itself with a slight shift introduced at each successive cycle of the process. Figure 6 show several structures that also explored the properties of a coil or coiling. A three-inch diameter wire coil was used to weave a membrane and explored its forming potential. The left side show three views a structure that forms a six-inch diameter ball (upper image) that can be gradually opened and flattened into the round membrane shown on the lower-left hand corner. The right side of Figure 6 shows two views of the same coiling and undulating membrane.

Figure 7 shows a project that explored the form generating potential of light when it is reflected through an uneven glass surface. The reciprocal relationship between the light, the shape of the uneven surface and the generated image was systematically explored, generating fluid and ghost like formations.

Figure 8 shows two views of a structure made by folding a sheet into a three-dimensional cellular pattern of triangles. This is an excellent way of exploring the dynamic and form generating potential of patterns (or patterned relationships).
Figure 5: Materials and Pattern Explorations, Left: corrugated cardboard, Right: coiled continuous basswood strip. Works by Selina Leung and Dan Linda Liu, 2001.

Figure 6: Materials and pattern explorations, woven flexible wire coil. Works by Katan J. Hanansen, 1999.
Figure 7: Materials and Pattern Explorations, reflected light explorations. Work by Ryan Odell, 2004.

Figure 8: Materials and Pattern Explorations, folded paper explorations. Work by Katan J. Hanansen, 1999.
Figure 9: Materials and Pattern Explorations, flexible wire mesh. Works by Justin H. Boon, 1997.

Figure 9 shows several forms and structures generated from the inherent dynamic properties embedded within a flexible wire mesh. Here again, a very basic elemental pattern, an orthogonal grid made with a thin flexible wire, has been explored as a dynamic integrated assembly with emergent properties. On the left is an improvised assembly of forms from the same continuous sheet. On the right is a more systematic assembly of woven undulating tubes. All of the forms shown were generated from the embedded potential of the material, its dynamic pattern and its emergent properties.

4 Conclusion

"Take trees: if I look at their trunks and branches, their leaves and veins, I know that the laws of growth and interchangeability can and should be something subtler and richer. There must be some mathematical link in these things. My dream is to set up, on the building sites which will spring up all over our country one day, a “grid of proportions”, drawn on the wall or made of strip iron, which will serve as a rule for the whole project, a norm offering an endless series of different combinations and proportions; the mason, the carpenter, the joiner will consult it whenever they have to choose the measures for their work; and all the things they make, different and varied as they are, will be united in harmony. That is my dream."

Le Corbusier [6]
“Originality is a return to origins”
attributed to Antoni Gaudi

Recent developments in architectural theory and practice reveal an increasing interest in the concepts and themes emerging out of our deeper understanding of complex and dynamic natural phenomena. The conceptual and philosophical aspirations of Le Corbusier, as indicated above, as well as Antoni Gaudi, Frank Lloyd Wright, Louis Sullivan, and other key central figures in the early formative period of modern architecture, directly relate to this current discourse and offer us insightful guidance. Le Corbusier dream of searching for dynamic design harmony through understanding Nature’s “laws of growth and interchange ability” in order to achieve “an endless series of different combinations and proportions,” along with Frank Lloyd Wright’s notion of “the life-principle” and of originality as coming from “the fountainhead if all forms whatsoever,” now these ideas seem more accessible and realizable to us. The objectives of this work, research and pedagogy specifically address these issues while, simultaneously, exploring and developing the rich potential of the new horizons being presently revealed and offered to the field of architecture.

References