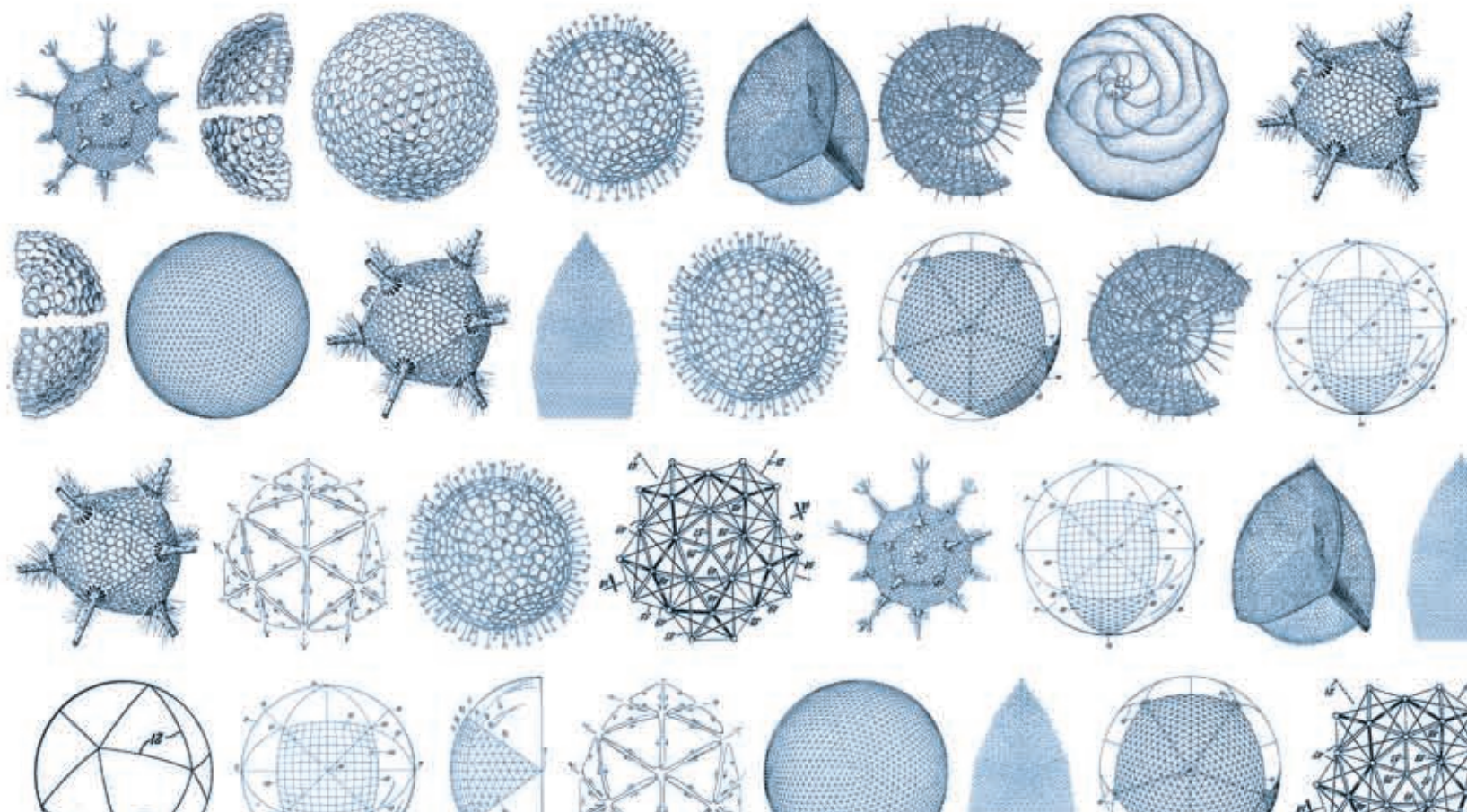


On Growth and Form

Organic Architecture and Beyond

Edited by Philip Beesley & Sarah Bonnemaison



ON GROWTH AND FORM
Organic architecture and beyond

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Preface

The essays in this book were originally written for the ACSA East Central Regional conference *On Growth and Form: the Engineering of Nature* held at the University of Waterloo in 2001. A selection of the papers presented at that gathering appear here. Each contributor revised and expanded their essay. We are grateful to Christine Macy for her generous editing of the essays, and we would also like to thank the Graham Foundation, Dalhousie University, the University of Waterloo, and Arriscraft Corporation, whose support made this project possible.

S. Bonnemaison and P. Beesley

Why Revisit D'Arcy Wentworth Thompson's *On Growth and Form*?

Sarah Bonnemaïson and Philip Beesley

Matter as such produces nothing, changes nothing, does nothing...[it] can never act as matter alone, but only as seats of energy and as centres of force. (Thompson 1942: 14).

In 1917, D'Arcy Wentworth Thompson published the result of his studies of morphology in *On Growth and Form*, arguing that the forms of plants and animals could be understood in terms of pure mathematics. The book became an immediate classic for its exploration of natural geometries in the dynamics of growth and physical processes. An extraordinary optimism is evident in this work, presenting a vision of the physical world as a symphony of harmonious forces. The book covers a vast range of morphological studies. He draws out the laws governing the dimension of organisms and their growth, the statics and dynamics at work in cells and tissues including the phenomena of geometrical packing, membranes under tension, symmetries, and cell division; as well as the engineering and geodesics of skeletons in simple organisms. Thompson conceived of form not as a given, but as a product of dynamic forces that are shaped by flows of energy and stages of growth. His eloquent writing and exquisite illustrations continue to inspire scientists, artists, and architects alike.

The authors who contributed to this volume re-visit Thompson's way of thinking and seeing the world, and apply it to their own work – in the realm of materials, construction, architectural form-finding and form-making. The array of design work featured here reveals an ongoing commitment to the vital pursuit of organicism, drawing upon contemporary art and science, and supported by a theoretical context for the work. In addition, critical readings provide alternatives to a traditional history of modern architecture that has celebrated the aesthetics of the machine. The essays invite the reader to bring together their own associations in applied and speculative paths of research

The essays present two diverging tendencies. Some are drawn to the patient craft and the technological optimism that is part of the search for design elegance. Key references here are Buckminster Fuller and Frei Otto's Institute for Lightweight Structures (IL). Other essays are drawn to the radical and unstable. In this vein, *Scientific American's* 150th anniversary issue on "Key Technologies of the 21st Century" tempered their usual American confidence with a sense of mounting anxiety,

The truth is that as technologies pile on technologies at an uneven pace, it becomes impossible to predict precisely what patterns will emerge. Can anyone today truly foresee what the world will be like if, for example, genetic

engineering matures rapidly to its full potential? If organisms can be tailored to serve any function, even becoming a living spaceship, can anyone guess what a 21st-century factory will look like? (Rennie 1995: xiii)

The experiments in artificial intelligence and genetic development presented in our *On Growth and Form* speak of continuous, restless transformation. When artifice extends its reach into nature, popular commentary would have it that this can only invoke the tragic dimensions of Mary Shelley's *Frankenstein*. Yet the critical culture surrounding this work has shifted from passive anxiety about tampering with life, to a more poignant, integrated involvement in complex systems. As the American theorist Donna Haraway says, "we're inside of what we make, and it's inside of us ... I am not interested in policing the boundaries between nature and culture – quite the opposite, I am edified by the traffic" (Haraway 1991:6).

Key Reference Works

Many architects and designers have explored the interface between architecture and nature, and we might refer briefly to their work to place this volume in its intellectual context. In his *Patterns of Nature*, Peter Stevens revealed the geometric patterns present in nature. He juxtaposes the branching of trees with branching arteries and rivers; images of crystal grains and soap bubbles.

To the casual observer, nature appears limitless in its ability to create and modify the shape of its creations. Upon closer examination, however, this myriad of forms is in fact constructed from a limited number of relatively simple shapes, determined by the combination of a number of constraints. The patterns and forms employed by nature are restricted by the constraints of physical space, the relations between area and volume, and the need to minimize resource consumption (Stevens 1974: flyleaf).

More recently, George Hersey's *The Monumental Impulse* and Norman Crowe's *Nature and the Idea of a Man-Made World* draw analogies between architectural forms and natural constructions – molecular, plant and animal. By pairing biological forms with architecture, Hersey establishes relations between physical structures and living organisms such as skeletons of birds and bridges, or winding DNA strands and a double spiral stair.

In the realm of computer-generated forms that mimic natural processes of evolution and transformation, John Frazer, author of *An Evolutionary Architecture*, is a key pioneer in the digitization of morphological transformations. Such work continues earlier studies into three-dimensional morphology by Haresh Lalvani – itself based on Buckminster Fuller's, Anne Tyng's and Louis Kahn's investigations into geometric transformations – and this line of study continues in the work of architects such as Greg Lynn.

A second group of architectural theorists have turned to vernacular construction with the conviction that such buildings and settlements express the interconnectedness

between humans and the landscapes they live in. Bernard Rudofsky is perhaps the best known of these, for his book *Architecture without Architects*, but many other architects in the 1950s and 60s were working in the same vein, such as Aldo van Eyck, Maurice Smith, and later, Christopher Alexander. They believed that the best architecture resulted from deep-seated cultural practices attuned to the landscape from which they arose. Myth here provides the link between nature and design. As Aldo van Eyck pointed out, myth serves as the repository of meanings linking built works to the natural world in all its cosmological force. Christine Macy and Sarah Bonnemaïson show the uses and misuses of myth in architecture and landscapes designed to express a notion of nature bound up with nation-building, in their book *Architecture and Nature: creating the American landscape*.

A third approach is the writing of the history of nature in architecture. Caroline van Eck, in her remarkable work *Organicism in Nineteenth Century Architecture*, convincingly argues that organicism was the prime theoretical referent for architects working long before the advent of modern architecture. Bruno Zevi and Peter Collins have argued that the organic ideal was a significant theme in twentieth century architectural theory, while more recent publications have traced the influence of organic thought in modernism, including Colin Porteous' *The New Eco-Architecture: alternatives from the Modern Movement*, and Sarah Menin and Flora Samuel's *Nature and Space: Aalto and Le Corbusier*. George Baird, in his *The Space of Appearance*, explores the impulse towards organicism among modernist architects and theorists such as Frank Lloyd Wright and Lewis Mumford, suggesting that a false dichotomy between abundance and scarcity allied the "organicist" project with consumerism. Detlef Mertins' essay "Bioconstructivisms" discerns conflicts within the modern tradition of organicism, positioning Thompson as a Platonic thinker in a transcendentalist tradition from the nineteenth century German zoologist Ernst Haeckel to Buckminster Fuller, and contrasting this lineage to other thinkers such as Frei Otto whose studies of structural systems emphasizes the differences, rather than the similarities between species. Mertins suggests that Otto's approach sidesteps essentialism, "to open up a world in which unique and complex structures result immanently from material exigencies, without being subject to any transcendent authority" (Mertins 2004: 368).

Essays Collected in this Book

The essays are organized into three sections. The first one, called "History and Criticism", covers the theoretical basis of organicism and examines canonical buildings through the lens of organicism. Ryszard Sliwka looks at the idea of natural order in architecture. He takes Ruskin's argument and brings it forward into the design practices of Le Corbusier and, more recently, Frank Gehry. Dörte Kuhlman traces the history of organicism and contextualizes modern architects within an intellectual milieu concerned about nature as an aesthetic idea. Kevin Nute interprets the organic forms of Louis Sullivan and Frank Lloyd Wright.

The 1960s and 70s were a period when determinism and behaviourism had the upper hand on environmental studies. This led to debates on the ethical and political dimensions of our relationship to nature. Buckminster Fuller, Pierre Teilhard de Chardin, and Frei Otto have each, in their own way, posed significant questions about our awareness that life on earth is a global phenomenon (Fuller 1969, Teilhard de Chardin 1959, Otto 1975-95). The three subsequent essays look at these influential figures and the impact they had on architecture. Christine Macy looks at the influence of philosopher Teilhard de Chardin on the back-to-the-land movement, new age philosophy and environmentalism. For example, living in geodesic domes was seen as a way to expand one's consciousness and "closing the loop" was a central ethical principle in early experiments in ecological living. Hadas Steiner turns her gaze to soap bubbles, noting their appeal to Frei Otto and others working on pneumatic structures. The fascination with inflatables, she argues, has to do with the way they express fluctuations in ambient conditions and the ease of construction in a do-it-yourself culture. Lastly, Sarah Bonnemaïson interprets Fuller's geodesic pavilion at Expo '67 as an engineered expression of nature's geometric patterns. As a result, she suggests, the building resonated with a younger generation that saw – in its transparency, weather-responsive shutters and earth-like form – a strong ecological message. "Reading the Organic" is the second section of the book. The first essay, by Nat Chard, explores two methods of representing a landscape: strictly pictorial *anamorphism* and a *stereotomic* folding of the picture plane. He carefully analyses their use in habitat dioramas from natural history museums. Chard is particularly interested in the dioramas of James Perry Wilson, a renowned diorama artist, and in order to understand how Wilson distorts an image to register a normal view, he built a camera to capture, in one photograph, the full range of transformations Wilson made to his picture planes. The essay relates the technical findings of his camera and speculates on the way our body is implicated when we view a landscape. The essay by fabric artist Ann Richards is a meditation on her work. She considers the forces involved in creating her textiles to be aspects of growth in D'Arcy Thompson's sense – that is, the stresses shown by the phenomenon of their creation. Her work relies on textures and shapes formed by the forces intrinsic to the fabric, resulting from the specific properties of materials and yarn twists. Finally, Reinhold Martin's essay brings us to the hidden aspect of our relationship to nature, looking at our impulse for destruction. Martin argues that when we look at the relationship between architecture and science we cannot avoid its connection to war. War accelerates the scientific and technological advances that are only later brought into the building industry. He supports his argument with many examples that take us from architecture to science, to war, and back to architecture.

The third and last section of the book is called "Nature as Teacher". With the rise of computer-driven design, morphology has once again emerged as a significant theme in contemporary architectural theory. This set of essays addresses this emerging interest in morphology with an emphasis on tensioned systems and lightweight structures. The

authors are architectural practitioners who draw from their study of D'Arcy Thompson. Thomas Seeböhm's essay relates the development of his computer program to design tensegrity structures as a way to help us describe nature. His aim was to develop a software that would allow the design to go from a two-dimensional topology of struts and cables to the corresponding resulting three-dimensional structure when released. Seeböhm draws out the poetry from abstract analytical concepts such as the role of prime numbers or the way tensegrity subsystems form larger wholes and reality. Manuel Báez argues that the coexistence of complexity and simplicity in nature challenges our imagination and he tries to address this apparent contradiction by building a series of installations. The forms are based on simple rules that eventually reveal the paradox of constrained and versatile freedom. Such research into geometries derived from nature, he argues, brings new energy to the study of architectural forms. Hajo Neis's essay reflects on Christopher Alexander's observations of natural processes in developing his "pattern language". These include the concepts of 'smooth unfolding', 'structure-preserving transformations', and 'formations of centers and fields of centers'. Neis shows the application of these processes in his own projects in Germany, the United States and Japan. Lastly, Edgar Stach describes his design project for an elephant enclosure in the Cologne zoo. Inspired by the balanced, flowing, weightless form of a cloud, he developed a structural concept for the roof that is realized with an iterative digital process of dynamic modeling and force-path calculation.

New Tools and Analytical Methods

D'Arcy Wentworth Thompson demonstrated new working methods for understanding the influence of physical forces in the environment, and the architectural projects in this book owe much to Thompson's research. They explore structural systems that use tension and 'tensegrity', in which forces animate the entire structure. Digital design tools now allow such complex interactions to be quantified and dynamically modeled, and digital prototyping and manufacturing play important roles in their realization. Instead of relying on centralized systems that resist environmental changes, new generations of buildings can accommodate shifting forces, distributing loads to better withstand undesirable deformation. Such buildings involve new methods of construction using chains of components and distributed structures.

Recent research confirms Thompson's empirical observations of biological form which showed that cell shapes are dictated by three-dimensional skeletons that mirror large-scale architectural space-frames. New developments in materials compatible with physiology, and miniature fabrication methods similar to those used for manufacturing computer chips have contributed to further this development in lightweight structural frameworks. Analytical tools that support visualization in space and time have led to miniaturization of established technologies such as magnetic resonance imaging (MRI) and positron emission tomography (an imaging by sequential sectional cuts, known as

PET), which permit the analysis of molecules and cells in living animals. The two-way street of evolutionary development involves molecular exchanges that can be detected with these tools. This ability to probe allows for the measurement of mechanical properties alongside observations of spatial and chemical dynamics. Adaptation to the environment through intimate linkages of natural forms and functions is now being described in mathematical detail. Molecular biology now asks critical questions about shape and structure at the scale of atoms, cells and organisms. A convergence of dynamic 'network' thinking from information technology has blurred the boundary between environment and organism. In turn, the natural world is being revealed in molecular detail as a dynamic ecology of interconnectedness.

Similarly, computer-aided design is capturing the geometric relationships that form the foundation of architecture, building upon now-established practices of form-finding and finite element analysis (which breaks down a continuous structure into many simple, linked elements in order to find optimal thicknesses and arrangements of supporting elements). New developments in parametric modeling permit control of design through models that can coordinate and update themselves. These systems can automatically update the entire model or drawing set based on changes as small as a joint or as large as the entire floor plan, offering flexible design of deeply nested relationships. In much the same way that mutations in nature generate biodiversity, individual variation in architectural components can be achieved economically. Parametric design practice employs 'dependency' networks akin to the complex process diagrams used to express relationships in natural systems, offering increasingly fine-tuned approaches to building component design. Using these tools, Architectural disciplines are poised to work with increasing effectiveness in responsive, interactive systems.

Whether through design practice or a critical perspective on design, the essays in this book ask what might we learn by revisiting Thompson's way of seeing the world, and apply the answers to their own work. The array of design work reveals an ongoing interest in the pursuit of organicism, and the critical interpretations of history provide alternatives to a traditional historiography of modern architecture that celebrates the aesthetics of the machine, by bringing to light some of the questions raised by the thorny relationship between nature and artifice that make our world. In their own way, these essays contribute to this important discussion.

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On Growth and Form

This collection of essays by architects and artists revisits D'Arcy Thompson's influential book *On Growth and Form* (1917) to explore the link between morphology and form-making in historical and contemporary design. This book sheds new light on architects' ongoing fascination with organicism, and the relation between nature and artifice that makes our world.

