NIKOS A. SALINGAROS

A THEORY OF ARCHITECTURE

Published by:
Sustasis Foundation
Portland, Oregon (USA)

Formatted by Harald Gottfried,
Umbau-Verlag, Solingen (Germany)

Printed in Europe (by MijnBestseller.nl)

For a list of the original places of publication of the unrevised texts, see CREDITS, page 262.

Library of Congress Cataloging-in-Publication Data
A Theory of Architecture
By Nikos A. Salingaros

ISBN 978-9-4638639-9-5

NIKOS A. SALINGAROS

A THEORY OF ARCHITECTURE

With contributions by Michael W. Mehaffy, Terry M. Mikiten,

Débora M. Tejada, and Hing-Sing Yu.

More than a decade in the making, this is a textbook of architecture, useful for every architect: from first-year students, to those taking senior design studio, to graduate students writing a Ph.D. dissertation in architectural theory, to experienced practicing architects. It is very carefully written so that it can be read even by the beginning architecture student. The information contained here is a veritable gold mine of design techniques. This book teaches the reader how to design by adapting to human needs and sensibilities, yet independently of any particular style. Here is a unification of genuine architectural knowledge that brings a new clarity to the discipline. It explains much of what people instinctively know about architecture, and puts that knowledge for the first time in a concise, understandable form. Dr. Salingaros has already published a widely-used book on urbanism, "Principles of Urban Structure" (2005), which is being praised as a fundamental synthesis and understanding of urban processes. He has experience in the organization of the built environment that few practicing architects have. The later chapters of this new book touch on very sensitive topics: what drives architects to produce the forms they build; and why architects use only a very restricted visual vocabulary. Is it personal inventiveness, or is it something more, which perhaps they are not even aware of? There has not been such a book treating the very essence of architecture. The only other author who is capable of raising a similar degree of passion (and controversy) is Christopher Alexander, who happens to be Dr. Salingaros's friend and architectural mentor.

PREFACE

by His Royal Highness

The Prince Of Wales

CLARENCE HOUSE

For some time now I have been fascinated by the work of the mathematician Professor Nikos Salingaros. His provocative new scientific perspective on architecture gives much food for thought, whatever one's views on the state of the modern built environment or the response of contemporary avant-garde architects might be.

Perhaps uncomfortably, Professor Salingaros challenges us to reconsider the relation between science and architecture. For him, the role of science is not merely to spin a dazzling, but ultimately meaningless, web of ever more technology. Rather, it is to better the human condition by putting the human being at the centre of our thinking and our building process. In so doing, he seeks to balance the daring sculptural conception of architecture that has become so extreme and, if I may say, so desperate in recent years.

A debate about these issues is critical and one which we should welcome in the interest of creating a better built environment. In some ways it is an intriguing return to the old humane ideals of the very early Modernists, adding some new tools to the rich "collective intelligence".

As a growing number of stakeholders seek today to identify common ground to improve the built environment, my view is that we must consider provocative new voices, arguing for fresh new thinking. Surely no voice is more thought-provoking than that of this intriguing, perhaps historically important, new thinker?

Charles

FOREWORD

By Kenneth G. Masden II

At a time when contemporary architectural discourse appears to be losing its theoretical footing, the shifting ground on which it stands seems to be convulsing with new-found speculations of every type. Architectural theorists from all over the world, wishing to take part in this re-stratification, seem to be desperate in their attempts to advance their ideas beyond the idiosyncratic ponderings of the dominant architectural elite. Looking outside architecture as a means to garner greater validity, their speculations have run the full gamut from mathematical theorems, to the postulates of French philosophers, to the loosely construed intimation of chaos theory and fractal logic into the domain of architectural design, to the near coercion of quantum mechanics and field theory as a means to extend their rhetoric. Each new theory offers but yet another invented way to conceptualize architecture.

The connection between architecture and the physical logic of our world is unquestionable. The recognition of this relationship is in-and-of-itself a step forward and backward at the same time. Back to a time when architecture was conceived and built within the limits of its materiality; and forward to the re-appropriation of ideas that were once nothing more than trial and error, but which can now be fully prescribed by modern science. The difficulty with such modern theories is in the translation or transference of ideas and information. Excluding any truly cross-disciplinary dialogue, these theories might well present little more than a glimpse into the unsettled realm that constitutes architectural theory today. In the midst of the clamor, it is becoming increasingly difficult to discern what are valid theories and what are not, or what is even useful information.

If we are to fully understand the architectural implication of advanced mathematics and science it seems only logical to engage authorities outside our own discipline, i.e. to seek real scientific knowledge from real scientists. As chance would have it, four years ago my path crossed that of Dr. Salingaros, a professionally trained Mathematical Physicist whose career had led him to discover a direct relationship between physical structures and processes, found throughout the material world, and that of man-made architectural and urban entities.

Having just taken my position in the School of Architecture at the University of Texas at San Antonio, Léon Krier asked if I had yet to meet his friend Nikos. What began as a tenuous, but interesting, first meeting has lead to a collegial relationship which is now going on five years. Over the course of this time Nikos has given me access to a way of thinking about the built environment which is more appositely grounded in the physicality of the real world, surprisingly not unlike pre-modern architecture.

Presented in this theory of architecture we see a series of principles for making a more livable world at every level, i.e. domestic, civic, urban, regional and global. To imagine what Dr. Salingaros envisions for the world around us, however, you must be prepared to leave the comfort of what you have come to believe to be architectural theory. You must be willing to look beyond the limits of ideology, to connect with a body of knowledge outside your own, one which has profound implications in the way we make buildings and find ourselves in relationship to the built environment.

Utilizing recently developed mathematics of fractals, information theory, and complexity, Dr. Salingaros reveals how advanced physics can have clear applications in the design and construction of human structures. In this book, he attempts nothing less than to reconstruct the relationship between man and the built environment: between life and matter, as it were. Architecture, for too long, has been left to a succession of aesthetic solutions through which entire civilizations expressed their indomitable "will to form". Architecture, as proffered by Dr. Salingaros, is seen more clearly in an intimate and inextricable relationship with the system of forces that give shape and rhythm to the physical world in which we live. Architecture at any scale, be it building or entire urban matrix, should no longer be defined by how it appears, but rather by how it relates to humans in their everyday existence. It must begin to assume a much greater role in the making of place, and today's architects must come to this realization quickly if we are to sustain any sense of humanity.

Taking as a point of departure the mind's compulsion to establish a connection with our environment, Dr. Salingaros shows how natural and man-made patterns serve as the principal conveyance of meaning about the world around us. He presents a theory of how these ideas and information are nested within a fractal scheme, putting forward a fractal theory of the human mind which helps to explain aspects of how we transfer meaning from our surroundings to our awareness. Through what is described as a symbiotic relationship between ideas, images, texts, and biological forms, Dr. Salingaros further explains how human culture consists of created objects as information that form an integral part of what we are, essentially extending our biological bodies into our environment. "A more human architecture", as Charles the Prince of Wales has called it, is shown here by Dr. Salingaros to carry with it the same intrinsic structural order that underlies all physical and biological entities.

Natural laws for generating buildings with intensely human qualities are found throughout the text, and are exampled in architecture from all parts of the world: for example Classical, Byzantine, Gothic, Renaissance, Baroque, Islamic, Near Eastern, and Far Eastern. Given the breath of theory, and the ideologically unbounded nature of the text, it is no wonder that at the time of this writing, "A Theory of Architecture" has already been translated into Farsi. It will be utilized in the service of non-western students who seek an alternative way in which to conceive of architecture, one which resides in a more authentic sense of existence outside the dominance of western architectural ideologies.

In this era of globalization, cultural entities too often succumb to the paradigm of perceived progress, one assumptive of change as presented by contemporary western models. Developing countries, in an effort to maintain their place in the world, will find the source of their new architecture within arm's reach; i.e. in the materials and practices of their region. Through this text they will understand the underlying principles that govern the manner in which the physical world reveals itself, recognizing at once its uncanny similarity to the rich vernaculars of their local traditions.

To fully appreciate Dr. Salingaros' vision, we must give credit to both Nikos and his long-time colleague Christopher Alexander, for whom he edited the recently published series of four books on the Nature of Order. It is through just such relationships that Dr. Salingaros has been able to ascertain and extend his theories and principles throughout the domain of theoretical physics and biology.

Driven by his passion and compelled by his knowledge, it is sometimes difficult for Nikos to contain his enthusiasm. In his zeal for what he sees as the unrealized potential of this work, he is quick to take aim at the architectural establishment, holding both architects and architectural academic institutions accountable for the dismal state of the built environment and education of design students. Understandably, this position has ruffled a few feathers along the way, but the integrity of the theories and principles he presents should not be underestimated or summarily dismissed due to the sometimes jarring nature of his critique. At the end of the day, both practicing architects and students, those who are seeking a greater clarity of how the physical world operates, will find this book instrumental in understanding how to operate within this new-found dimension. To date, my students have taken great interest in Dr. Salingaros' work, finding ever greater possibilities in their design and a much greater appreciation for the real architecture of the real world.

CONTENTS

Fractal simplicity, in which there is self-similar scaling, replaces the outdated notion of rectangular simplicity. Architectural units on different scales are able to cooperate in an intrinsic manner to achieve an emergent property, which is not present in the individual components. The theory of hierarchical systems from Engineering Science explains how to relate different scales to each other. In buildings, the correlation between architectural scales determines whether a structure is perceived as coherent or incoherent, independently of its actual design, form, and composition. This Chapter presents a scientific proof of why organized detail (i.e. small-scale ornament) is essential to the overall coherence of architectural forms. | P 63

Chapter 4.

THE SENSORY VALUE OF ORNAMENT

Ornament is a valuable component in any architecture of buildings and cities that aims to connect to human beings. The suppression of ornament, on the other hand, results in alien forms that generate physiological and psychological distress. Early twentieth-century architects proposed major stylistic changes — now universally adopted — without having a full understanding of how the human eye/brain system works. | P 84

Chapter 5.

LIFE AND COMPLEXITY IN ARCHITECTURE FROM A THERMODYNAMIC ANALOGY

Using an analogy with thermodynamics, a simple mathematical model can be constructed following ideas of Christopher Alexander, which estimates certain intrinsic qualities of a building. This model predicts a building's emotional impact. The architectural temperature T is defined as the degree of detail, curvature, and color in architectural forms; whereas the architectural harmony H measures the degree of visual coherence and internal symmetry in the visual structure. The impression of how much "life" a building has is measured by the quantity $L = TH$, and the perceived complexity of a design is measured by the quantity $C = T (10 - H)$, where $10 - H$ corresponds to an architectural entropy (disorder). With the help of this model, new structures can be designed that have a dramatically increased feeling of life, yet do not copy existing buildings. | P 105

Chapter 6.

ARCHITECTURE, PATTERNS, AND MATHEMATICS

This Chapter posits the importance of architectural patterns in every human being's intellectual development, examining how twentieth century architectural attitudes towards decoration and pattern have impoverished our experience of both mathematics and the built environment. | P 129

Chapter 7.

PAVEMENTS AS EMBODIMENTS OF MEANING FOR A FRACTAL MIND
(WITH TERRY M. MIKITEN AND HING-SING YU)

This Chapter examines the role of pavement design as a vehicle for conveying meaning, taking as a point of departure how the mind establishes a connection with our environment. A theory is developed for how ideas and information may be stored within a fractal scheme. By putting forward a fractal theory of the human mind, we can explain some aspects of how we transfer meaning from our surroundings to our awareness. Interacting with our environment is an important theme seen during the evolution of the brain. | P 144

Chapter 8.

MODULARITY AND THE NUMBER OF DESIGN CHOICES
(WITH DÉBORA M. TEJADA)

This Chapter analyzes one aspect of what is commonly understood as "modularity" in the architectural literature. There are arguments to be made in favor of modularity, but we argue against empty modularity, using mathematics to prove our point. Empty modules eliminate internal information, and their repetition eliminates information from the entire region that they cover. Modularity works in a positive sense only when there is substructure to organize. If we have a large quantity of structural information, then modular design can organize this information to prevent randomness and sensory overload. In that case, the module is not an empty module, but a rich, complex module containing a considerable amount of substructure. | P 159

Chapter 9.

GEOMETRICAL FUNDAMENTALISM
(WITH MICHAEL W. MEHAFFY)

"Geometrical fundamentalism" aims to impose simple geometrical solids such as cubes, pyramids, and rectangular slabs on the built environment. This defines a characteristic of twentieth-century architecture and planning. The more complex connective geometry found in pre-twentieth-century architecture and in the architecture of traditional cultures is replaced. Geometrical fundamentalism may be in part responsible for the resentment the rest of the world feels against the industrialized western nations, because it replaces traditional buildings and cities with structures that are perceived as inhuman. A philosophy about geometrical shapes thus has an enormous socio-economic impact, by generating forces against globalization. The modernist movement promised a radical new utopian society based on a fundamentalist belief in pure abstractions. The extremely influential twentieth-century architect and urbanist Le Corbusier was entranced by the reductionist machine geometry of his time, and imposed it upon buildings and cities around the world. This misapplication of elementary abstractions constitutes a gross cognitive error, and fails to create satisfying human environments — the core purpose of architecture and the building arts. It parallels other totalitarian abstractions of the twentieth century, and this point will be discussed here. | P 172

Chapter 10.

DARWINIAN PROCESSES AND MEMES IN ARCHITECTURE: A MEMETIC THEORY OF MODERNISM
(WITH TERRY M. MIKITEN)

The process of design in architecture parallels generative processes in biology and the natural sciences. This Chapter examines how the ideas of Darwinian selection might apply to architecture. Design selects from among randomly-generated options in the mind of the architect. Multiple stages of selection generate a design that reflects the set of selection criteria used. The goal of traditional architecture is to adapt a design to human physical and psychological needs. At the same time, however, any particular style of architecture (adaptive or not) constitutes a group of visual memes that are copied for as long as that style remains in favor. Darwinian selection also explains why non-adaptive minimalist forms have been so successful at proliferating. The reason is because they act like simple biological entities such as viruses, which replicate much faster than do more complex life forms. Simple visual memes thus parasitize the ordered complexity of the built environment. | P 195

Chapter 11.

TWO LANGUAGES FOR ARCHITECTURE

Design in architecture and urbanism is guided by two distinct complementary languages: a pattern language, and a form language. The pattern language contains rules for how human beings interact with built forms — a pattern language codifies practical solutions developed over millennia, which are appropriate to local customs, society, and climate. A form language, on the other hand, consists of geometrical rules for putting matter together. It is visual and tectonic, traditionally arising from available materials and their human uses rather than from images. Different form languages correspond to different architectural traditions, or styles. The problem is that not all form languages are adaptive to human sensibilities. Those that are not adaptive can never connect to a pattern language. Every adaptive design method combines a pattern language with a viable form language, otherwise it inevitably creates alien environments. | P 220

Chapter 12.

ARCHITECTURAL MEMES IN A UNIVERSE OF INFORMATION

I describe here a symbiosis between ideas, images, texts, and biological forms. Human culture consists of created objects as information, which form an integral part of what we are — i.e., an essential extension of our biological bodies into our environment. This sensory, informational extension and mechanism for interaction defines a universe of information. With the advent of electronic communications, a relatively autonomous virtual world has been created. The space of information has proved a fertile breeding ground for the same informational entities — called “memes” — that formerly inhabited only human minds and artifacts. Architectural memes that took generations to diffuse through a restricted society can now spread around the world almost instantly, and will eventually alter its physical appearance. This Chapter aims to understand this process. | P 242

INTRODUCTION

In a short period of time, contemporary architecture has captured the imagination of millions of people the world over. Thick, glossy, and expensive books and magazines featuring photos of the world's premier architects along with their buildings adorn the living-room tables and libraries of those who can afford them. Millions of dollars are spent on flashy new buildings, when something much more reasonable could do. Developing countries with severely limited budgets frantically compete to engage the most fashionable of our "star" architects to build something for them, too. Architecture is thus highly visible in our media. It is clearly "in" with the times, thus providing a magnet for young persons wishing to make an exciting and challenging career choice.

What is it that a young student actually studies to become an architect, however? Is there a body of information to be mastered, such as for example the foundations of biology or medicine? There is a practical side requiring training and an apprenticeship of several years, but where are the thick books containing all of accumulated architectural knowledge, labeled "Principles of Architecture" (analogous to, say, "Principles of Physics") and running into one thousand pages? Surprisingly, thick architecture books are either full of pictures of contemporary "star" architects and their buildings, or they only address the history of architecture, featuring dead architects and their buildings. Architecture today seems to have no basis — not one that uses architectural traditions and analytic thought for today's designs. Students are taught by example that buildings of the past offer no lessons applicable to the contemporary built environment.

This book presents some ideas that I have explored in trying to discover the basis for architectural design. The search has led me to consider the application of science and mathematics to architecture. This approach has proved remarkably fruitful in establishing new and useful results. Most architects know of the historical application of ancient mathematics such as proportional ratios — but it is not this type of mathematics that actually governs general architectural form. Rather, it is the more recently developed mathematics of fractals, information theory, and complexity (concepts that will be explained in this book). I have presented these results in a manner I hope will be useful to practicing architects as well as to students who are seeking a greater clarity of how the physical world operates, and how this ties into architecture.

Each chapter consists of one of my published papers in architecture. It is my intention that collectively, these research articles can be used as a textbook for architectural design, or as supplementary material in a studio course. Individual chapters have indeed been used in this manner in many schools around the world ever since their initial publication. Their main message is that architecture can and should be based on principles that stand scientific scrutiny and experimental test. I present many new results, so no similar treatment of the principles underlying architectural design exists at the present time. My own architectural formation is due to my long involvement with Christopher Alexander in helping him to edit his monumental book, *The Nature of Order*, so, naturally, my work is profoundly influenced by and is complementary to his.

A student who sets out to study architecture should have a book that describes how to conceive and build an environment suitable for human activities. That is, after all, what everyone assumes that architects do. Design knowledge now resides solely in the minds of practicing architects and architectural academics. No clear guide exists to help the aspiring young architect deal with the physicality of form, founded on ideas open to questioning and verification. Instead, students are urged to use their imagination, though it is uninformed and limited. They are exposed to an extremely narrow stylistic vocabulary. When they look to the past (which is full of instructive examples) they are told to look to the future (which is unknown and thus of no educational value). "Approved" images seem to correspond only to each instructor's favorite architects, surely an insufficient reason to justify a lengthy education in architecture school. Even if it is to be followed by an apprenticeship in some architectural firm, this system does not train young persons to use a body of practical knowledge as principles of design.

All this seems anachronistic, and even dangerous. The reason is that a closed system of untested knowledge lends itself to corruption and dogmatism. Myths are created and perpetuated — the opposite of the openness of the scientific method, which seeks to demystify. Reflect for a moment on how scientific research is done. Someone announces the results of an investigation that links a cause with an effect, then his or her colleagues try their best to disprove them. The method by which they were obtained is scrutinized, as well as their ability to be verified by other researchers. If the results withstand this "trial by fire", then they are allowed to stand. When a result is verified independently of possible prejudices or of any agenda by those who proposed it, then it enters the permanent body of knowledge, at least until it is superseded by a more refined or more general result.

Architecture no longer works through any sort of empirical or experimental verification. This book represents my attempt to correct this condition, which is to me highly unsatisfactory. Architecture synthesizes a diverse body of disciplines in a manner that we react to directly. I did not write this book for scientists; I wrote it for practicing architects and students of architecture, in a language they can understand and apply. The task is so overwhelming, however, that it appears much more difficult now than when I first started on this project twelve years ago. This generation of architects has an abstract conception of architectural space, surfaces, structural coherence, and materials. As a result, contemporary architects are not often receptive to new knowledge about their discipline.

To achieve my aims, it is necessary to do the following, at the very least:

(*i*) Derive laws for how matter comes together to define buildings that give pleasure to human beings.
(*ii*) Explain, using scientific arguments, why people derive pleasure and satisfaction from some forms but not from others.
(*iii*) Find a basic commonality with past and present architects who have sought the same goals.

(*iv*) Explain why architects have not universally adopted known techniques that succeed in producing emotionally-nourishing buildings, and instead build structures that seem only to generate anxiety.
(*v*) Suggest how schools can train architects to create buildings that are emotionally and physiologically nourishing.

To work on any single one of these topics is daunting. Nevertheless, I have been forced to do all of these at the same time. The scientific results that I present contradict current architectural beliefs, and thus criticize architects who have ignored those results now and in the past. One of the explicit aims of modernism — and a major reason for its success — was to overcome nature through innovation. To do this, however, often requires doing the opposite of what is needed and what is natural. This violates people's feelings and our most basic instincts, because it goes against nature. Architects had to invent a new, "intellectual" justification for their forms, because they clearly contradicted our emotions and even our physiology.

It is essential in any serious analysis to explain what drives contemporary architecture, and why its objectives may be radically different from what architecture's aim ought to be. And who determines that aim? On the one hand, we have architects who argue in terms of images with an undeniable novelty supported by a volume of non-scientific writings; on the other hand we have the precedents of biological and natural structure, which are supported by traditional architectures. I cannot honestly present results that differ fundamentally from what is actually practiced today, without implying that present-day practices are misguided. This criticism has been unavoidable from a scholarly point of view. However unwillingly I take this iconoclastic stand, I defend it with the best arguments I can come up with.

People tend to trust figures of authority (such as prominent critics, "star" architects, and architectural academics in our top schools), who talk in the media about "architectural theory". I believe they are mistaken. What is currently labeled "architectural theory" — with few exceptions — is unverifiable, and hence not very useful for design. Not only does the architectural community not have a body of theory as such, but it is confused as to what a viable theory would look like. The professional organizations and bodies of accreditation, acting the role of watchdogs in other professions, seem to ignore this contradiction here. Nevertheless, young and sensitive practitioners are at long last seeking true architectural knowledge, welcoming science as their ally. Through computer applications, architects have begun to study a complexity of form and function hitherto undreamt of.

Courageous persons tried to achieve similar goals, but faced stiff opposition. Starting from my friend and mentor, Christopher Alexander, they include Léon Krier, Charles, the Prince of Wales, and the late Friedrich Hundertwasser. Each one, in his own unique way, has argued for a more humane architecture for our times. Each of these persons has spoken out against the dehumanizing effect of contemporary architecture, and each one has been criticized in the media (and, on occasion, harshly attacked and ridiculed). What they have to say has so far been kept out of architecture schools. However, as a result of the proliferation of the internet as a universal information source, the message is finally being communicated to young architects and students. This represents the beginning of an architectural revolution, or, as architects would say, a paradigmatic shift.

We have in our possession the means to build a new environment that equals the greatest architectural achievements of the past. People can once again experience architecture as something nourishing, instead of as a vehicle for novelty (often creating dysfunctional buildings that lead to anxiety and depression). It is just that today's architects are not informed about the natural laws for generating buildings with intensely human qualities, so that they might choose to incorporate them into their design. There is also resistance from the architectural establishment, and it is an ideological one. This is about to collapse, however. Once a new generation of architects emerges that is not beholden to outdated ways of doing things, and to unquestioning support of an entrenched power elite, it will be receptive to laws that enable an adaptive architecture. I predict a new architecture of unprecedented beauty, justly appropriate for the new millennium.

ACKNOWLEDGMENTS

I am indebted to Christopher Alexander, who inspired me to devote my research energy to understanding the built environment. Working with him on his book *The Nature of Order* during the twenty years prior to its publication taught me much of what I know about architecture and urbanism. He has generously encouraged me over all these years. More than that, he provided a solid point of sanity in an architectural world driven by images, fashions, and opinions. My work utilizes and expands on his ideas in many ways. A full appreciation of the material presented here can only come from reading his monumental work.

Many thanks to the Alfred P. Sloan Foundation for generously supporting my research into the scientific laws of architecture, through a grant during 1997-2001. My coauthors on four of the Chapters, Michael W. Mehaffy, Terry M. Mikiten, Débora M. Tejada, and Hing-Sing Yu, provided invaluable input. Individuals who contributed useful advice and comments on one or more chapters include Michael Benedikt, Carl Bovill, Alfonso Castro, Carl Davis, Ollivier Dyens, James M. Gallas, Dmitry Gokhman, Robert E. Hiromoto, Peter Hochmann, Wai-Kwok Kwong, David Miet, Terry M. Mikiten, John Miller, John C. Rayko, Lynn A. Steen, Gregory P. Wene, Sir Christopher Zeeman, and Mary Lou Zeeman. I thank all of them.

The chapters in this book are based on previous publications, and I am grateful to the various journals for their permission to use the published material. I started to write this book by publishing each completed topic as a separate research paper. It is only recently that I arranged these papers on different but related architectural topics into a comprehensive book.

Finally, Kenneth G. Masden II helped me directly in the demanding task of editing the individual chapters into a coherent monograph, in a way that would be useful to architects and architecture students. In addition to his careful reading of the text and numerous suggestions for revisions, inviting me to lecture from this book to his senior studio class generated valuable student feedback. Some sections were rewritten and expanded, the notation and terminology were made uniform, and explanations were added throughout the text. The result is a treatise that is much more coherent than the chapters as they appeared originally. Following his advice, the book also includes many new figures that were not present in the original articles.

Chapter One

THE LAWS OF ARCHITECTURE FROM A PHYSICIST'S PERSPECTIVE

1. INTRODUCTION.

It is my contention that architecture is an expression and application of geometrical order. One would expect the subject to be described by mathematics and physics, but it is not. There is as yet no clear and accepted formulation of how *structural order* is achieved in architecture. Considering that architecture affects humankind through the built environment more directly than any other discipline, our limited understanding of the actual mechanism that creates *structural order* is surprising. We have concentrated on understanding natural inanimate and biological structures, but not the systematic patterns reflected in our own constructions.

There exist historical buildings that are universally admired as being the most beautiful (see Section 2 in this Chapter, below). These include the great religious temples of the past (Fletcher, 1987) and the cultural wealth contained in various indigenous architectures (Rudofsky, 1964; 1977). Both were built by following some rules of thumb, which can be deduced from the structures themselves. One general set of empirical rules has been analyzed and collected in the *Pattern Language* of Christopher Alexander (Alexander *et. al.*, 1977).

Laws for *structural order* underlie both physics and biology, and I expect similar laws should hold for architecture as well. Alexander proposes a set of geometrical rules that govern architecture, derived from biological and physical principles (Alexander, 2004). They are based on the hypothesis that matter obeys a complex ordering on the macroscopic scale. *Structural order* requires only that forms be subdivided in a certain manner, and that the subdivisions be made to relate to each other. Even though forces such as electromagnetism and gravity are too weak to account for this, volumes and surfaces apparently interact in a way that mimics the microscopic interaction of elementary particles. Architecture can therefore be reduced to a set of rules that are akin to the laws of physics.

Structural order also refers to perceived form, and thus encompasses two components of architecture that have been segregated in the discussions of the past several decades: tectonic structure, and surface design. I don't wish to mix surface qualities with built structure; but our sensory mechanisms respond just as well to visual designs as to tectonics. Thus, *structural order* is due to both of these aspects of built form, which are distinguished simply by scale. This book spends considerable effort to relate scales to each other, and to human response. *Structural order* depends upon human perception, hence it cannot be judged strictly from abstract formal criteria. This is a concept familiar to physicists, where the observer becomes part of, and influences the behavior of, a quantum system. An underlying theme of this inquiry is that architecture exists in the universe of human beings, and cannot be isolated into an abstract realm of its own. The basic criterion may be stated as: "if we respond to it in any way, then it is a component of *structural order*".

Using analogies with the structure of matter, three laws of *structural order* are postulated here (Section 3). They are checked in three different ways: by agreeing directly with the greatest historical buildings of all time (Fletcher, 1987); by agreeing with fifteen properties abstracted by Alexander from creations throughout human history (Alexander, 2004); and by agreeing with physical and biological forms. This result represents a successful application of scientific analysis (i.e., the physicist's approach) to understanding and solving a highly complex problem, which has up until now resisted a scientific formulation.

The three laws of *structural order* can be applied to classify architectural styles in a way that has not been done before (Section 4). Whereas most traditional architectures follow the three laws, contemporary and modernist buildings often seem to be doing the opposite of what the three laws say. By modernist, I mean the architecture introduced in the 1920s, which led to "International Style" and minimalist buildings. This result categorizes traditional architecture into a separate group from the architecture of the twentieth century, which is not surprising, since their architects wanted their buildings to be different. It will be useful to get a clearer conception of the corresponding *structural order*. It appears that all buildings are created by a systematic application of the same three laws, whether in following them or in opposing them.

Thus far, the results do not distinguish which architecture is "better". Nevertheless, Alexander, in company with Charles, the Prince of Wales, prefers a more humane architecture, which is most often found in traditional forms. They believe that traditional architecture is more suited to humankind for fundamental reasons (such as human physiology and psychology) and not merely as a matter of taste. Section 5 of this Chapter presents arguments to support this view. The basis of those arguments is the sense of comfort one feels from a building and the universality of its *structural order*, which is the way the architecture hold together on a visual, physical, and tectonic level.

2. RULES OF BEAUTY AND ORDER IN PAST TIMES.

Every distinct civilization or different period in the past has left us a set of rules, usually implicit, that help produce the ultimate ideal in beauty. Each set of rules is relevant to the ornamental tradition of a particular time, the availability of indigenous materials, the local climate, or an underlying religious ritual, and defines architectural forms that are beautiful. What is important is that these very different buildings and objects are seen as beautiful by most people today, who live outside the time and culture that produced them. This implies the existence of universal laws governing *structural order*.

There is no difficulty in applying a traditional set of architectural rules to contemporary buildings. A Greek temple in Japan (as a bank), or a Chinese temple in the

United States (as a restaurant) can be beautiful, if built by following the rules appropriate to their particular form. Such rules tell us how to duplicate something from an earlier culture or different people. They cannot, however, be generalized or easily adapted to a different set of forces and circumstances. Rather what we need now, and what architects are always looking for, is a prescription for building something beautiful that is not constrained by a rigid and possibly irrelevant tradition.

Rules that are genuinely independent of any specific culture and time can be derived by approaching architecture as a scientific problem. I give three laws governing *structural order* that include, as special cases, most of the previous sets of architectural rules derived throughout history for creating beautiful buildings. I then show that the rules for building identifiably modernist structures simply do the opposite of what is needed to achieve *structural order* in architecture. This result singles out two distinct classes of structures in the history of human construction.

Different types of *structural order* also give rise to different experiences for a building's user. Many contemporary and earlier twentieth-century buildings (though certainly not all) that follow the industrial model are perceived as unpleasant by their users. This may be true for their visual aspect, and especially so for practical functions (entry and exit, working, circulation, etc.) that are supposed to take place in those buildings. It would be good to have some explanation for why this is, so we can fix it. Public reaction against certain architectural styles has been noted before (Blake, 1974; Wolfe, 1981), and is forcefully expressed by Charles, the Prince of Wales (Charles, 1988; 1989). Despite all these criticisms, however, the modernist aesthetic (which influences styles that succeeded modernism) remains deeply entrenched in our society, overriding questions of user reaction and comfort that might threaten to judge it as flawed.

Proponents of modernism have identified their credo with the technological progress of the twentieth century. In the minds of many people, post-war industrial progress is falsely linked to, if not outright due to, the expansion of modernist architecture, and for this reason they are reluctant to question it. It has become automatic for developing countries to build the most modern-looking buildings as the first step towards modernization. Nevertheless, it is now accepted that modernist building programs in the preindustrialized world have largely been disastrous in their urban and environmental consequences (Blake, 1974).

The widespread proliferation of modernist architectural typologies is a socio-historical phenomenon, and thus amenable to scientific analysis. Explaining modernism's extraordinary success occupies the last third of this book, Chapters 9 though 12. Though at the core of any theory of architecture, this topic cannot be studied using purely architectural reasoning; therefore, new techniques that utilize ideas from evolutionary biology had to be developed to explain historical events.

3. LAWS FOR ARCHITECTURE.

The following laws of *structural order* are inspired by and rely on Alexander's results; in particular, his "fifteen properties" in Book 1 of "The Nature of Order" (Alexander, 2004). They have grown out of my discussions and interaction with Alexander over the past twenty-two years. I tried to formulate a set of laws that might be easier to remember than Alexander's "fifteen properties". It is of course not possible to replace fifteen properties by only three laws, but hopefully my interpretation can help to bring Alexander's "fifteen properties" into sharper focus by approaching the problem of *structural order* from a slightly different, complementary direction.

Table 1.1. Three Laws of Structural Order.

Law 1. Order on the smallest scale is established by paired contrasting elements, existing in a balanced visual tension.

Law 2. Large-scale order occurs when every element relates to every other element at a distance in a way that reduces entropy.

Law 3. The small scale is connected to the large scale through a linked hierarchy of intermediate scales with a scaling ratio approximately equal to $e \approx 2.7$.

The word "entropy" in Law 2 is the technical term for randomness or disorder. Although a standard term in physics, it does not commonly arise in architecture. In Law 3 above, e is a ubiquitous mathematical constant, the base of natural logarithms. I will discuss how to apply this number to design in this and the following two Chapters. Scaling in Law 3 relates components of different sizes, and "hierarchy" refers to the rank-ordering of all those sizes.

Several independent arguments supporting these laws are presented below. The first two laws govern the two extremes of scale: the very small and the very large; and the third law governs the linking of all different scales. Each law gives rise to several distinct consequences; together the three laws define a set of possible rules for architecture. They are validated because their immediate consequences appear to correspond to reality.

3.1. Order on the Small Scale.

I will establish an analogy with the way that matter is formed out of contrasting pairs of elementary components. From the vacuum in quantum electrodynamics arising out of virtual electron-positron pairs, to nuclei formed from bound neutrons and protons with opposite isospin, to atoms formed of bound electrons and nuclei of opposite charge, the composition of matter follows the same basic pattern. (All these examples are on the subatomic, atomic, and molecular levels). The smallest scale consists of paired elements with the opposite characteristics bound together. The binding is a result of complementarity. Coupling keeps opposites close to each other but does not allow them to overlap, because they would mutually annihilate (i.e., cancel each other); their close separation creates a dynamic tension. Keeping units of the same type next to each other does not result in binding.

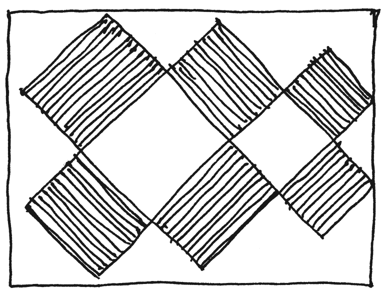
Applying this concept to architecture gives us Law 1, which states: **"Order on the smallest scale is established by paired contrasting elements, existing in a balanced visual tension"**. Local contrast identifies the smallest scale in a building, thus establishing the fundamental level of *structural order*. This scale should be relevant to the observer — in regions where a person walks or sits or works, contrast and tension are needed at the smallest perceivable detail; in areas distant from human activity the "smallest" scale is much larger.

Structural order is a phenomenon that obeys its own laws. It connects built structure with visual structure on the human scale. Its fundamental building blocks are the smallest perceivable differentiations of color and geometry. Whereas visible differentiation on the small scale is not necessary to define physical structure, it is in fact necessary for *structural order*. This is demonstrated in architecture and in most objects made before the twentieth century. Classical Greek temples have marvelous contrasting details. This was also true of color, but the original coloration has been lost with time. To see the effective use of color contrast, look at the extraordinary fifteenth century tiled walls in Iran, Islamic Spain, and Morocco.

There are several important consequences of the first law.

(1a) Basic elements have to couple with each other. Like elementary physical components, the smallest fundamental units should have shapes that permit them to combine into more complex shapes (see Figure 1.1).

Figure (1.1)
Elements on the small scale couple through contrast.



(1b) Basic units are held together by a short-range force, i.e., one that is very strong when objects are close, but has no effect when they are far apart. The only way to do this using geometry is to have interlocking units with opposite and contrasting characteristics. There are several ways to achieve contrast with materials: shape (convex-concave); direction (zigzags); color hue (red-green, orange-blue, violet-yellow); and color value (black-white) (see Figure 1.2).