THE UNIVERSITY OF MANITOBA

ORGANIZED COMPLEXITY IN ARCHITECTURE

by

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When is a collection of parts a whole? This question was first put to me two and one-half years ago by Professor Denis Jesson in conjunction with a "kit of parts" building on which I was working. It is a simple question; indeed, upon first speculation a rather ingenuous one. However, after more thoughtful consideration its ingenuousness takes on new and profound meaning for it is a question so fundamental as to enquire of the very basis of one's understanding of the world. It is a question which asks: What makes man and his environment a universe? What makes a sequence of sounds a symphony? What makes a complex of mechanisms a machine? What makes layers of tissues an organism? What makes a constellation of spaces a place? It is a question of the ORDER of all things.

This question was the seed; from it has grown a continuing investigation into the nature of order, particularly with respect to architecture, of which this thesis is but the most recent manifestation.

Prior to this thesis my investigations have been conducted through two complementary means. The first, which consciously began with the initial question two and one-half years ago and has continued, more or less without interruption, until the time of this thesis, was the design study of the order of particular architectural entities. The second, which began one year later, was the written study of the general attitude of holism, particularly as represented by the thought of Frank Lloyd Wright, Buckminster Fuller, Jan Christiaan Smuts, and Christopher Alexander[1].

In retrospect it is evident that the scope of these studies was much too circumscribed. In both "order" was conceived out of context and out of time: out of context in that it was conceived as an absolute, as something unqualified by circumstance; out of time in that it was conceived as immutable, as something unqualified by changing circumstance. That is to say the order which should exist within the architectural entity, or any entity for that matter, was conceived to be that of Fuller's tensegrity structures floating in outer space -- each part of the whole absolutely interdependent with every other part of the whole, and all together completely independent of anything else. Hopefully the present work will go some way toward enlarging this "idealized" view of order.

With regard to these past studies as well as the thesis at hand I would like to acknowledge the role of Professor Jesson as mentor and friend.

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[1] This study provides historical context for this thesis both in the sense that it is concerned with the thought of other times and in the sense that it reflects my own thought immediately prior to the present work. As such I have included it as an appendix to this thesis.

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INTRODUCTION

The creation of architecture involves men of many different disciplines and interests. In conjunction with the architect, clients, engineers, financiers, technicians, manufacturers, public officials, and contractors, among others, all contribute to the definition of the architectural entity. However it is the architect alone who is responsible for the ORDER of the architectural entity -- how the various parts of the architectural entity are disposed with respect to one another so as to constitute a totality appropriate, on all levels, to the variety of demands placed upon it. It is to this responsibility that this thesis is addressed.

To cope with the organized complexity[1] of the architectural

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[1] Dr. Warren Weaver in the 1958 Annual Report of the Rockefeller Foundation distinguishes between three types of problem. The first type is a problem "in which one quantity...depends primarily upon a second quantity..." (p.7). That is to say this first type of problem involves the relationship of a single element to another. It is a "PROBLEM OF SIMPLICITY". The second type is a problem "in which the number of variables is very large, and one in which each of the many variables has a behaviour which is individually erratic, and may be totally unknown. But in spite of this helter skelter or unknown behaviour of all the individual variables, the system as a whole possesses certain orderly and analyzable average properties". (p.11) That is to say this second type of problem involves the probable behavior of a gross totality. It is a "PROBLEM OF DISORGANIZED COMPLEXITY". The third type is a problem which will "often involve a considerable number of variables; but much more important than the

entity the architect obviously must understand the principles by which its parts may be ordered. Indeed these principles are the very essence of the architect's discipline. It is most surprising, therefore, that the overall architectonic of these principles, an understanding of which is the only reasonable basis on which to deal with the organized complexity of the architectural entity, is but vaguely understood within the profession in general. I would go so far as to say that, rather than the conservativeness of clients, the limitations of technology and budget, and the demands of building by-laws, and aside from the general confusion of aims which characterizes our contemporary society, it is the lack of a clear understanding of the overall architectonic of the principles which order the architectural entity that is the major source of the architectural profession's general inability to create a truly satisfactory human habitat.

The intent of this thesis, therefore, is to construct a framework for the principles which order the architectural entity. This will be accomplished in two parts:

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mere number of variables is the fact that these variables are all interrelated. That is to say, the really important characteristic of" this type of problem, "as contrasted with the disorganized situations in which statistics can cope", is that it shows "the essential feature of organization". (p. 13) This third type of problem involves the relationships among various elements which makes them a unity. It is a "PROBLEM OF ORGANIZED COMPLEXITY".

Within the first part of the thesis a generic framework for the principles which order all entities will be constructed. This framework will derive directly from the fundamental aspects essential to the concept of "entity". Part One is thus a basis for dealing with the organized complexity of all entities.

Many of the concepts contained in this part of the thesis will be drawn from the growing body of contemporary work which is concerned with establishing a theory of the order of all things. The widely accepted label for this work, General Systems Theory, is not so much a reflection of the state of the work, however, as a statement of the intent of the workers. As it now exists General Systems Theory is a collection of partial theories which are related but which do not constitute a complete and integrated general theory. In essence Part One is my initial investigation into General Systems Theory. It is not a full-blown theory, of course, it is merely a framework in which some of the principles which order entities are considered.

Within the second part of the thesis the framework constructed within the first part will be brought into a specifically architectural focus. The particular nature of the architectural entity will be set out in discussions of its different orders. In each discussion issues which have long been problematical for architects will be considered. Part Two is thus an introduction to the organized complexity of the architectural entity.

PART ONE

ORGANIZED COMPLEXITY

CHAPTER 1. ENTITY

1.1 Essential Nature

The first thing which must be determined in order to understand the nature of entities is in what this nature originates.

Consider the parts of which an entity is made. The same parts which make up one entity generally can be used to make another entity of essentially different nature. For example the same boards and nails can be used to construct a boat as well as a building. The same elements which make up certain acids can be used to make the water and fertilizer which nourishes the fields. The same words which make up a nature poem can be used to make up a Boy Scout camping manual. Evidently, as the same parts can be used to make essentially different things, the nature of an entity is not determined by its constituent parts. This is not to say that a "silk purse" can be made out of a "sow's ear" of course. Obviously the nature of an entity is limited by the inherent capabilities of the parts which make it up. Nevertheless, it is clear that the parts do not determine the nature of an entity.

However that which determines the nature of an entity is readily apparent in the preceeding examples. Consider the difference between the collection of individual parts which can be made into an entity and the entity itself. It is evident in the difference between a stack of boards and a pail of nails, and the boat, building, or whatever is made from these parts just as it is evident in the difference between individual elements and the numerous complex chemicals into which they can be composed, or in the difference between a dictionary full of words and the literature into which these words can be fashioned that the nature of an entity is determined by the ORGANIZATION of the constituent parts. That is to say it is the RELATIONSHIPS among the parts rather than the parts themselves which determine the nature of an entity.

1.2 Wholeness

Three basic types of relationship can exist among the parts of an entity. A part is DEPENDENT upon the other parts of the entity if it is asymmetrically related to those parts so that it is affected by but has no effect upon them. Any change in the "affector" parts therefore not only causes a change in the entity as a totality but also in the part which is dependent upon them. A part is INDEPENDENT of the other parts of the entity if it is not dependent upon them. Any change in these other parts causes a change in the entity as a totality but leaves the part in question unchanged. A part is INTERDEPENDENT with the other parts of the entity if each is dependent upon the others. Thus a change in any part not only causes a change in the entity as a totality but also in every other part. Clearly independence, dependence, and interdependence form increasingly cohesive bonds between the parts of an entity.

These three basic relationship types, in varying strengths and proportions, combine to form the set of relationships which orders the parts of an entity. Sets of relationships range in proportion from the extreme of complete independence, in which each relationship of the set is one of simple independence, through sets compounded of varying measures of independence, dependence and interdependence, to the other extreme of complete interdependence in which each relationship in the set is one of simple interdependence. The former extreme of complete independence results in "entities" whose parts are related, if only in the nominal sense, so that each part is independent of every other part. The latter extreme of complete interdependence results in entities whose parts are so related that each part is dependent upon every other part. These extremes are the poles in a continuum of relatedness. The more highly independent the parts of an entity the more it tends to be simply a collection of parts, an AGGREGATE, and hence only nominally an "entity". The more highly interdependent the parts of an entity the more it tends to be a unity, a WHOLE.

Consider a set of rocks scattered about a field in a random manner as a structural entity. Obviously as the individual

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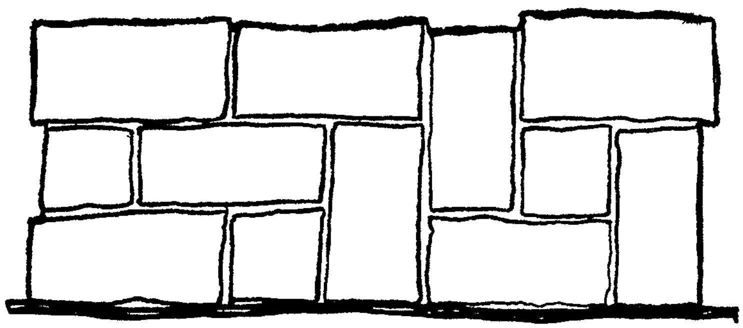

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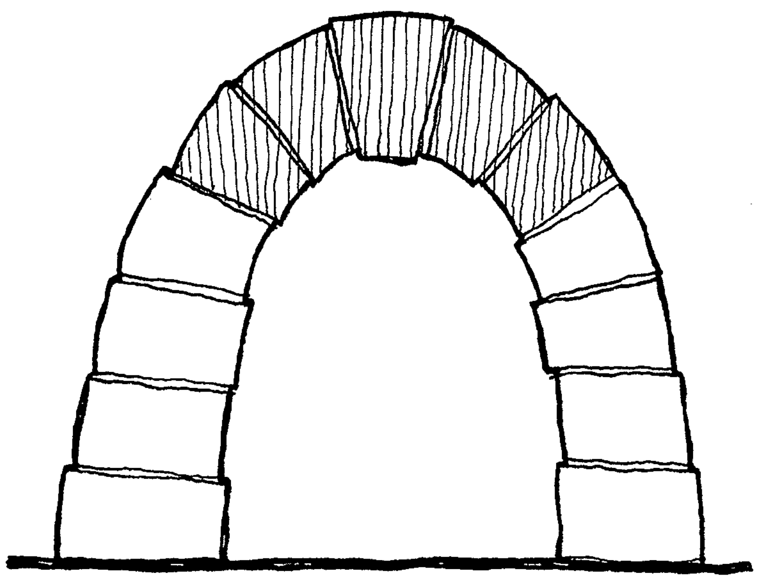

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rocks are structurally independent the set is an aggregate, and can only nominally be considered an entity. Even if the rocks are reorganized so that they form a line around the field one rock high and one rock deep (1) they are still structurally independent[1]. A change in position of any individual rock while it modifies the nature of the line leaves the position of the other rocks unchanged. However, if the set of rocks is reorganized again so that instead of a line it forms a wall (2) its nature as a structural entity becomes more whole-like. Some of the rocks are now structurally dependent upon other rocks so that a change in the position of the supportive rocks causes a change in the position of the dependent rocks as well as in the wall as a totality. Finally if the set of rocks is again reorganized, this time into an arch (3), it becomes even more whole-like. Here each rock is structurally dependent upon the rocks below it while independent of the rocks above it with the important exception of the rocks which occupy the central portion of the arch. These rocks, a subset of the total set, are so related that each rock is structurally dependent upon every other rock. The elements of this subset are completely interdependent, they act as a structural whole.

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[1] Joern Utzon's "additive architecture" is a structural aggregate in this sense. This is not to imply, however, that in respects other than structure, spatial organization for example, it may not be more whole-like.

CHAPTER 2. SYSTEM

2.1 System

A SYSTEM IS AN ABSTRACTION OF AN ENTITY ON THE BASIS OF THE ORGANIZATION OF ITS PARTS. To understand nature as the complex symbiosis of a myriad of organisms in interlocking and overlapping roles interrelated with an environment of organic and inorganic materials and ultimately dependent upon solar energy is to understand nature as a system. To understand the city as social man and his matrix of artifacts; beliefs and laws, signs and symbols, institutions, communication and transportation networks, enterprises and facilities, urban spaces and buildings, in a mutually sustaining and fulfilling relationship is to understand the city as a system. To understand meaning as the pattern of relationships of a concept is to understand it as a system. A system is an expression of the essential nature of an entity, an expression of its wholeness[1].

Although a building is a single entity architecture has traditionally been understood as two distinct types of systems. As a material system architecture is understood to be a utilitarian artifact. As such it is composed of structural, mechanical, and

[1] its wholeness -- that which makes it a whole.

environmental subsystems which are organized into a plan facilitating various activities. Architecture as a utilitarian artifact is what is traditionally meant by the term "mere building" implying that its value was purely extrinsic. As a phenomenal system architecture is understood to be a work of art. As art a building is a domain, a place of unique character which arises from the relationships between the building and its inhabitants. Architecture as art is traditionally differentiated from "mere building" in that its value is purely intrinsic. All buildings can be understood in terms of either or both of these two systems types although not every building has significant systemic properties in either or both respect.

As an abstraction, a particular understanding of an entity, a system is relative to the intention of the abstractor. Thus whereas Picasso's "Bull's Head" may be a meaningfully organized work of art to the 20th century art audience it may not represent a meaningful organization to the Bicycle Club of America. Sigfried Giedion has discussed the different conceptions of the essential nature of architecture in history. According to Giedion the Egyptian, Sumerian, and Greek civilizations understood architecture to be the relationship of masses in space, from the time of the Romans until the 19th century architecture was understood to be the relationship of interior spaces, while the 20th century understands architecture to be the relationship of both masses in space and interior space.

However, though relative to intention, a system is not an arbitrary abstraction of the relationships of an entity. Only the essential relationships, those which make the entity a whole, constitute a system. To understand a symphony orchestra as the interaction of the instruments of four sections defined with respect to the principles by which they create sounds; the strings, brass, woodwinds and percussion, is to understand it as a system. To understand a symphony orchestra as the interactions of the instruments of four sections defined with respect to categories of weight is to completely destroy the sense in which the orchestra operates as a system. A system is an abstraction of the ESSENTIAL relationships of an entity.

2.2 Fundamental Aspects

A system can be understood in terms of three fundamental aspects -- being, behaving, and becoming. Being is the pattern of relationships among the elements of a system. Being is the morphology of a system. Behaving is the act, arising from the interactions of the elements of a system, which maintains the system in the face of the internal and environmental stresses acting upon it. Behaving is the morphostasis of a system. Becoming is the change within a system by which it adapts to changes in the internal and environmental stresses acting upon it. Becoming is the morphogenesis of a system.

As transient events behaving and becoming are purely temporal aspects of a system. Being, on the other hand, is non-temporal, existing out of time altogether. Being is the matrix of the event. Behaving is the act and becoming is the change which occurs in this matrix.

Being, behaving, and becoming are parallel aspects of a system -- one does not follow from the other. Still, each may be seen in terms of the others: Being is the product of past becoming, the present embodiment of a continuing process of change. Being may be maintained, the process of change interrupted, only so long as behaving can obviate the stresses which come to act upon the system. Behaving is a manifestation of being, a response dictated by the stresses which act upon, and within, the system. Becoming is a process of change in being and behaving, a process of adaptation

Obviously the intent of analyzing a system into these three fundamental aspects is to promote conceptual clarity and hence facilitate discussion. To this end these aspects will be used to organize the remainder of Part 1 of this paper. At the same time, however, it must be remembered that, although conceptually distinct, being, behaving, and becoming must be understood in conjunction with one another for they are one in the system.

CHAPTER 3. BEING: SYSTEM MORPHOLOGY

Being is the pattern of relationships among the elements of a system.

Being is the product of past becoming.

Being is maintained by behaving.

3.1 Elements

Elements are the basic units which are ordered by the set of relationships which constitute a system. Each element is inherently capable of entering into a certain number or range of relationships of which the relationships of the system are a subset. It is important to differentiate between elements in a free state and elements within a system. In a free state the element exists in isolation, with the potential of numerous, possibly contradictory, relationships. In a system, however, an element is ordered by specific relationships which define the actual, as opposed to potential, nature of the element. Thus in considering an element of a system the context, the set of relationships, which defines that element is necessarily part of the consideration.

The importance of the distinction between the element in a free state and as part of a system is evident in the fact that a single "free" element may assume fundamentally different natures in the context of different systems. A piece of wire, for example, used to complete an electric circuit or to tie up a bundle of newspapers exhibits different characteristics in each context. So too, four potentially identical columns spaced beneath a beam at maximal distances from one another are actually different in this context. (4) Thus the central columns carry twice the load of the end columns due to their different relationships to the load. In the context of the system it is irrelevant that they are potentially identical[1].

Perhaps the most readily perceived examples of the distinction between the potential and actual (as defined by the context) natures of elements occur, naturally enough, in the realm of perception. The familiar gestalt example of a square of middle grey on fields of black and white clearly shows the defining power

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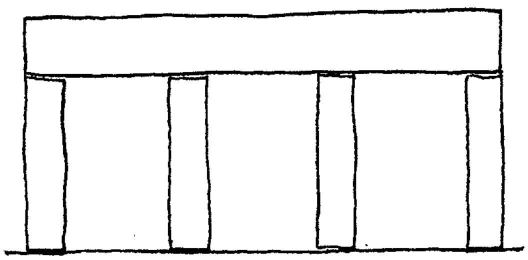
[1]Many architects would find this structural system objectionable because equal elements are used to perform unequal tasks. Although this objection might be brought on the grounds of material economy I tend to think the real objection is founded on another source, after all, as it has been repeatedly pointed out by Buckminster Fuller among others, in comparison to other technologies architecture is almost always grossly uneconomic in its use of materials. The real objection to this system is that it does not diagram the proportional relationships between the various columns -- the perceptual structure is not a "diagram of the forces" at work in the actual structure. Thus the objection to this system is a question of the relationships between two different systems representations of a single entity. This is an important question which will be considered at length in Chapter 9.

of the context of an element. (5)

The columns of the Parthenon are an interesting example of this phenomenon in that though the potential characteristics of the columns vary the fact that their contexts vary also makes the actual, that is perceived, columns identical. (6) The context of the corner columns differs from that of the other columns in two respects. Unlike the interior columns which are bounded on both sides by other columns the corner columns are unbounded on one side. Also because of their position on the end of the row they are seen in silhouette against a bright sky while the interior columns are seen against the background of the temple walls. To compensate for this difference of context each corner column is thicker and the intercolumnar space between it and its immediate neighbour is narrower than in the typical case. Thus perceptually identical elements result from the masterful use of potentially differing elements in differing contexts.

3.2 Multi-level Systems

Multi-level systems are systems which contain elements which, in themselves, are systems containing elements. In this way systems are contained within systems until some fundamental



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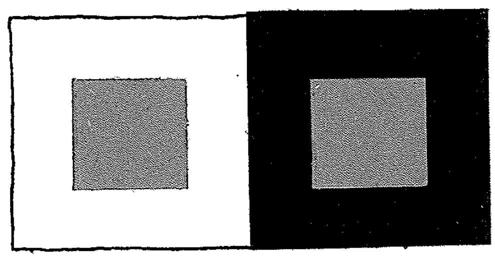

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level is reached where the elements can be considered primary[1]. Of course, a primary element need not be primary in the sense of being an ultimate irreducible particle, it is merely the most fundamental element of concern in a particular context. Thus for a mechanical engineer the primary elements of an internal combustion engine would be its pistons, cylinders, cam shaft, block and so on whereas for a metallurgist the atomic constituents of these parts would constitute primary elements. Only for the nuclear physicist would the primary elements be ultimate irreducible particles.

Systems, especially complex systems, exhibit a great proclivity to assume a multi-level structure. Consider the following parable:

> "There once were two watchmakers, named Hora and Tempus, who manufactured very fine watches. Both of them were highly regarded, and the phones in their workshops rang frequently - new customers were constantly calling them. However, Hora prospered, while Tempus became poorer and poorer and finally lost his shop. What was the reason?
>
> "The watches the men made consisted of about 1,000 parts each. Tempus had so constructed his that if he had one partly

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[1]To crystalize the nature of multi-level systems as systems within systems various authors have proposed that units with the dual aspect of being simultaneously system and element be designated by some special term. R. W. Gerard has suggested "org" and A. Koestler has suggested "holon". However as the great majority of units in any concern have this dual aspect it seems more economical to me to make a special designation for units of single aspect; i.e., "primary element".

> assembled and had to put it down - to answer the phone say - it immediately fell to pieces and had to be re-assembled from the elements. The better the customers liked his watches, the more they phoned him, the more difficult it became for him to find enough uninterrupted time to finish a watch.
>
> "The watches that Hora made were no less complex than those of Tempus. But he had designed them so that he could put together subassemblies of about ten elements each. Ten of these subassemblies, again, could be put together into a larger subassembly; and a system of ten of the latter sub-assemblies constituted the whole watch. Hence, when Hora had to put down a partly assembled watch in order to answer the phone, he lost only a small part of his work, and he assembled his watches in only a fraction of the man-hours it took Tempus."[1]

The lesson of the parable is that in a world of less than perfect efficiency, trial and error, false starts, and dead ends (unsuccessful assembly attempts due to caller interruption) systems which are built up from intermediated stable forms, that is multi-level systems, come into existence more quickly and hence are more probable than single-level systems of equal complexity.

This lesson applies equally to natural and man-made systems. That natural systems evolved from intermediated stable forms; physio-chemical systems predominantly by chance combinations,

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[1]Herbert A. Simon, "The Architecture of Complexity". Proceedings of the American Philosophical Society, 106: p.470, 1962. Note: Simon's quantitative analysis of the relative efficiencies involved here indicate that in the most conservative case Hora would be about 4,000 times more efficient than Tempus.

biological systems predominantly by chance variations, and socio-cultural systems by both chance variation and combination, is a generally accepted fact. On the other hand, man-made systems, although in many respects similar to natural systems, have a distinctly teleological nature. In this respect their characteristics reflect the problem solving procedure. Problem solving is not simply a process of trial and error. It is a process of SELECTIVE trial and error in which a partial solution which seems to indicate the desired solution serves as a directive for future trials. The final solution develops from a number of partial solutions much as natural systems evolve from intermediate stable forms. Thus, the problem solving procedure itself tends to be a multi-level system. Of course, the solution, need not necessarily be a multi-level system, however, it is not unlikely. In any event the problems of implementation and maintenance of man-made systems, as illustrated in the parable are such as to reinforce the natural predisposition of the problem solving process for multi-level systems.

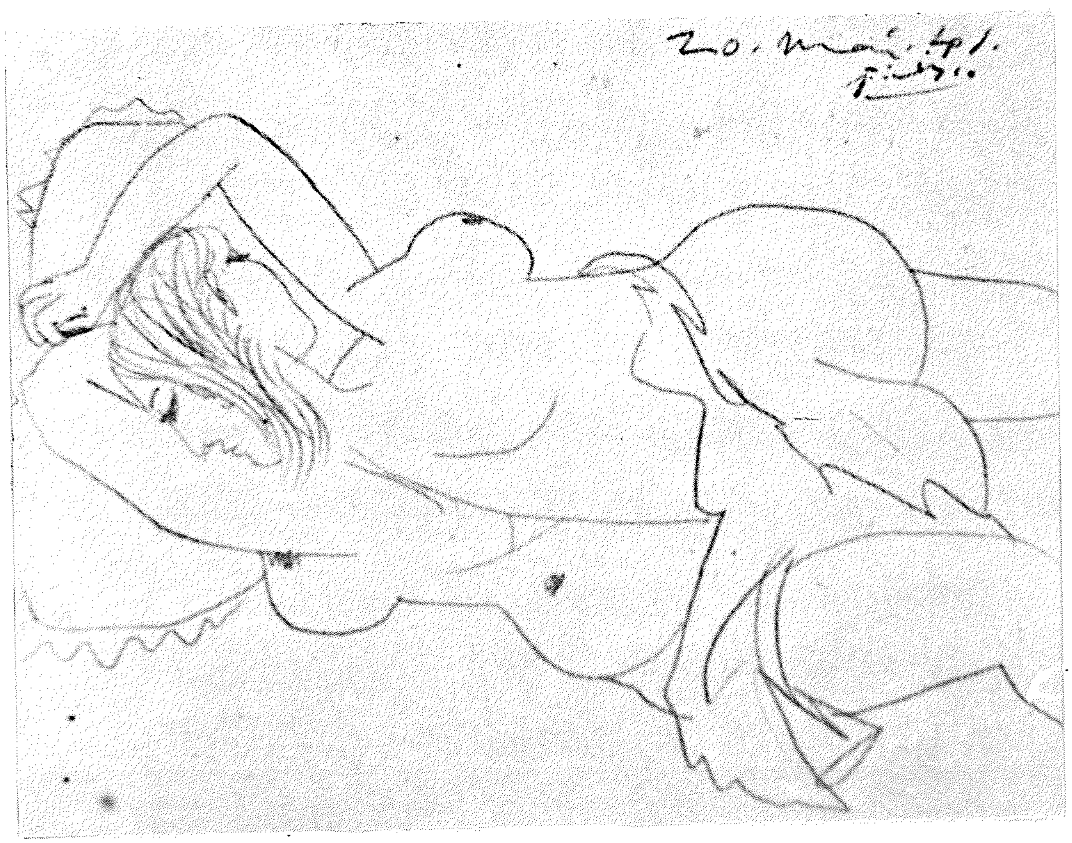
3.3 Overlap

It is a common phenomenon for an element to be a member of more than one system, that is, for systems to overlap. One need only consider the number of different interest groups of which he is a member to realize this fact. The subsystems of great works of art abound with overlap, as do the subsystems of the natural ecosystem. Even the prosaic telephone pole, which is often a member of both the telephone and street lighting systems, is an example of overlap.

Overlap is not a defining characteristic of systems, however. That is to say, overlap is not a relationship between systems, it is a coincidence of elements within systems, a function of the element and not the system. Overlap is an accompanying characteristic of systems by which the relative complexity or capability of systems may be augmented. Thus it is obvious that given a fixed number of poles the range of the telephone and street lighting systems is considerably augmented by the sharing of poles; that is, by overlapping. Perhaps more impressively much of the ambiguity and multiplicity of aspect of works of art derives from overlapping subsystems. Picasso's "Sleeping Women" of 1941, for example, is especially graphic in this regard. (7)

There is one important type of system in which overlap is not common. This is the type of system developed by design science, that discipline of design in which the linear thought processes of deductive reasoning predominate or are aspired to. City planning and architecture, understood as utilitarian artifacts, are generally thought to belong to this discipline.

Christopher Alexander in his seminal paper "A City is



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not a Tree" distinguishes between natural and artificial cities. Natural cities are cities which have arisen more or less spontaneously over many years. Manhattan, Montreal and San Francisco are examples. Artificial cities are cities which have been deliberately created by designers and planners. Chandigarh, Brazilia and the British New Towns are examples. Thus the distinction between the two types of city is that one is a result of a "natural" process of accommodation while the other is a product of design science.

It is generally agreed that while natural cities are sometimes wearing due to their excesses they are vital human environments while artificial cities seem to be stifled by designed "neatness" and "orderliness" which deadens rather than enlivens human life. Not surprisingly, Alexander suggests that this is because natural cities are rich with overlap, ambiguity and multiplicity of aspect which is lacking in the strictly hierarchical order of artificial cities. Overlap is not less orderly than the simplistic order of compartmentalization but more so. It is "a thicker, tougher more subtle and more complex view of structure."[1] Of course, as soon as people inhabit these artificial cities they tend to generate thick

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[1]Christopher Alexander, "The City is not a Tree", Part 2, p. 58.

overlapping webs of relationships quite irrespective of the theoretical order in which they find themselves. This is an inevitable aspect of human nature and the reason most artificial cities have what richness they have. Nevertheless, as the physical system can be either a positive or negative reinforcement to the system of human relationships which it must house, it is the prime responsibility of the designer that the physical system be as positive a force in human social life (and this includes isolation where it is appropriate) as is possible.

3.4 Internal Specialization

A system is internally specialized when its constituent elements are more or less unique in structure and/or function with respect to one another. For example a football team is internally specialized; each of the players has his own function and to a certain extent his own particular structure, whereas a tug-of-war team is not internally specialized; its players are essentially identical. Like overlap, however, internal specialization is not a defining characteristic of systems. A garbage dump, for example, while it may be made up of highly differentiated elements has very few systemic properties. Rather, like overlap, internal specialization is an accompanying characteristic of systems by which the relative capability of a system may be augmented. This is the raison d'étre of the process of increased specialization which has characterized the evolution of human society, for example.

There are certain general types of specialization which are essential to the existence of many systems. Centralization occurs when one element or subsystem assumes a dominant role in the operation of the system such that a small change in it is reflected by considerable change throughout the system. This is the form of specialization which pertains whenever there is a situation of authority, of leader and led. However, centralization need not have the rigidity which it is generally conceived to have. It can be variable so that authority belongs to that element or subsystem most able to deal with the particular situation at hand. This, for example, is one of the fundamental tenets of most interdisciplinary teams.

The "skin" or boundary which surrounds many systems is another general type of specialization (See section 4.4, "Open/Closed Systems") A boundary acts as an environmental monitor allowing inputs necessary to the system's survival through its various energy and sensory gates and insulating the internal workings of the system from any environmental "noise". This is the function of the skin, sense and digestive organs in organisms, and of the housing, gauges or meters and fuel supply in artifacts.

In many internally specialized systems a differentiation between essential and non-essential elements exists so that in times of stress the system as a whole can extend its "life" by sacrificing non-essential elements which, in many cases, can be regenerated in later less stressful periods. The human organism is an excellent example:

> "Without food many organs waste away, the body burns fats, carbohydrates and proteins to supply energy for two organs which don't waste away at all (or not until much later) and which are clearly essential to the continuing functioning of any of the organs - the nervous system and the heart. One can get along without a digestive system quite well under starvation conditions, a great wasting of muscles can be tolerated, the reproductive system isn't important, and so on; but if the heart stops pumping or the brain functioning, the whole system is gone."[1]

Naturally internal specialization has commonly been an important characteristic in complex entities such as buildings. Nevertheless internal specialization has been of particular concern in the work of Le Corbusier, especially in his investigations into the nature of the wall. To begin Le Corbusier separated the two primary functions of the traditional wall into a load-bearing frame and various boundary-defining infills. The logic of this separation was the obvious ease with which the infilling elements could now be

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[1] R. W. Gerard, "Hierarchy, Entitation and Levels", p. 224

manipulated.

The advantages of specialization ultimately became clear, although with great struggle, in the exterior wall which Le Corbusier developed. In order to utilize the possibility of the great spatial and visual openess which the structural frame allowed the primary material used in the exterior wall was glass, even on the west elevation (e.g., Cité de Refuge). In anticipation of the great temperature differential this membrane would have to mediate Le Corbusier invented 'le mur neutralisant' which consisted of double panes of glass between which heated or cooled air could be passed to maintain the interior temperature at desired levels. Unfortunately this invention did not prove adequate. After much anxiety and in admitted desperation Le Corbusier invented another device which was more successful. This device was the brise soleil, an "egg-crate" hung on the exterior of the building which shielded the glass from the direct rays of the sun. Thus by differentiating the functions of the traditional wall and then further differentiating the functions of the wall as a boundary, or as Reyner Banham has said, "to replace additively element by clip-on element the performance factors that the massive wall contained homogeneously and organically,"[1]

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[1] Reyner Banham, The Architecture of the Well-Tempered Environment, p. 155

Le Corbusier was able to achieve a rich and variable spatial conception.

However, the benefits of specialization are not automatic, they are only potential as witness Le Corbusier's efforts in his dealing with the interior wall. As it was the frame's function to carry the actual load of the building it seemed logical, if not necessary, to Le Corbusier to make this manifest by reducing the substance of the boundary elements to the absolute minimum. Thus he reduced the interior wall to a hollow sandwich of insubstantial sheet material. The acoustic difficulties this engendered became immediately apparent. To alleviate this problem a sheet of lead was suspended between the two halves of the sandwich. Unfortunately this wall, too, was unsatisfactory. Eventually Le Corbusier conceded defeat and resumed use of masonry and other "materials friendly to man". Failure to produce a satisfactory interior wall was essentially a failure to establish the right relationships between the right materials. Specialization in itself guarantees nothing.

3.5 The Multi-purpose Element

When differing specialized subsystems overlap the shared elements are often of a multi-purpose nature.[1] For example, the blood vessels in warm-blooded animals not only act as conductors of blood and its contained nutrients but also are part of the homeostatic temperature control of the body expanding and contracting in response to the needed adjustments of body temperature. Multi-purpose elements are elements which are defined simultaneously by two or more different sets of relationships.

Multi-purpose elements like specialized elements exist commonly in complex systems such as buildings.

However, as the work of Le Corbusier was of particular interest with respect to the specialized element, the work of Frank Lloyd Wright is of particular interest with respect to the multi-purpose element. Illustrative of this use of the multi-purpose element Reyner Banham describes an interesting detail of the

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[1] In Complexity and Contradiction in Architecture, Robert Venturi discusses the "double-functioning element". From his use of examples it would appear that he understands the concept to be similar to the concept of "multi-purpose element" as used here. However he falls prey to the common misconception that the specialized element and the multi-purpose element, or in his terminology, double-functioning element, are opposites. "The double-functioning element has been used infrequently in Modern architecture. Instead, Modern architecture has encouraged separation and specialization . . ." (p. 40) In actual fact the multi-purpose element is a special type of specialized element; that is, a multi-specialized element.

Robie House:

> "Corresponding to the glazed openings of the outer wall, and inset in the lower flat portion of the ceiling, are a series of oaken grilles, made into abstract designs by the insertion of small cubes of oak between the slats of the grille. An electric lamp, controlled by a dimmer, is set above each of these grilles, and casts a modulated dappled light through it onto the floor in front of the windows. (8)
>
> "However romantic the effect may be judged, there can be no doubt that this is an entirely appropriate installation, in a situation where the customary sconces or wall brackets would have made little visual sense. But these oaken grilles may have a further function which is nothing to do with lighting, to which the clue is given, once more, by the text of the Wasmuth portfolio:
>
>> The gently-sloping roofs, grateful to the Prairie, do not leave large airspaces above the rooms, and so the chimney has grown in dimensions and importance, and in hot weather ventilates at the high part the circulating air-space beneath the roofs, the fresh air entering beneath the eaves through openings easily closed in winter.
>
> "The Robie house has such openings beneath the eaves and its chimney has grown a separate limb projecting on its western side, with the characteristic pattern of ventilator bricks indicating an extract of some sort. But if, in winter when the openings under the eaves had been 'easily closed', air was still required to circulate through the roof-spaces to carry away the damp, it could enter through the lighting grille, acquiring useful heat from the lamps and from sundry hot pipes in the roof. There would then be just room for it to pass between the flange of the steel joists and the under-side of the roof covering, and so pass into the higher part of the living-room above the raised ceiling, and thence out by way of the ducts in the brickwork of the added limb on the side of the chimney."[1]

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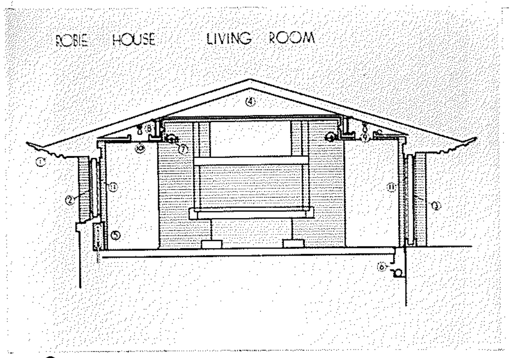
[1] Reyner Banham, The Architecture of the Well-Tempered Environment, p.120

Because of the programmatic complexity of domestic life the multi-purpose element occurs within the Prairie House on the scale of the detail. In more particularized building types Wright was able to utilize the multi-purpose element much more dramatically on larger scales.

The auditorium of his Unitarian Church in Madison, Wisconsin is a striking example of multi-purpose space. Unlike the "high school gymnasium" notion of multi-purpose space in which the space is multi-purposed solely in that it is a neutral envelope which can accommodate (but never really satisfy) a variety of activities, Wright's auditorium is designed in direct response to the opposing needs of the sacred service of the church and the secular gatherings of the community. Each of these activities is facilitated by a single space which rises dynamically along its longitudinal axis. Oriented toward the "aspiring prow" the sacred ceremony takes place within a space which demands consideration of man's larger concerns. (9) Oriented in the opposite direction, towards the hearth, the secular performance takes place in an intimate, almost domestic, space. (10) Thus simply by the ingenious specialization of orientation Wright has created a truly multi-purpose space.

Another example of Wright's masterful use of the multi-purpose element exists in the four identical concrete slabs which constitute the vertical structural elements of the Price Tower. (11)



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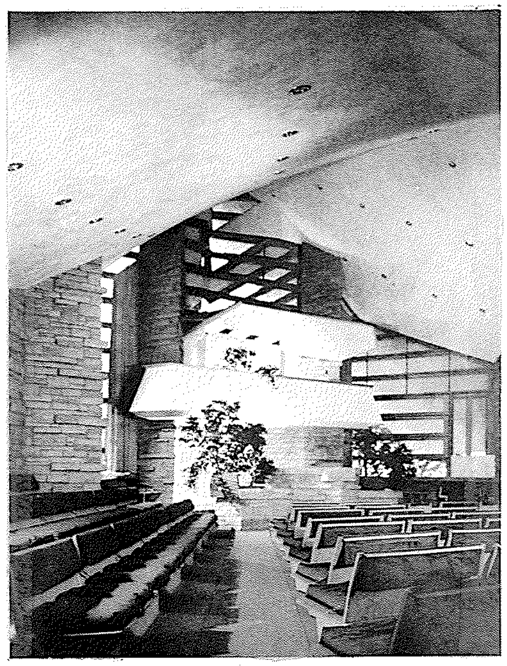
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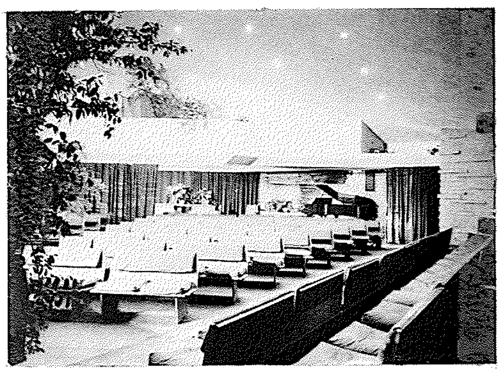
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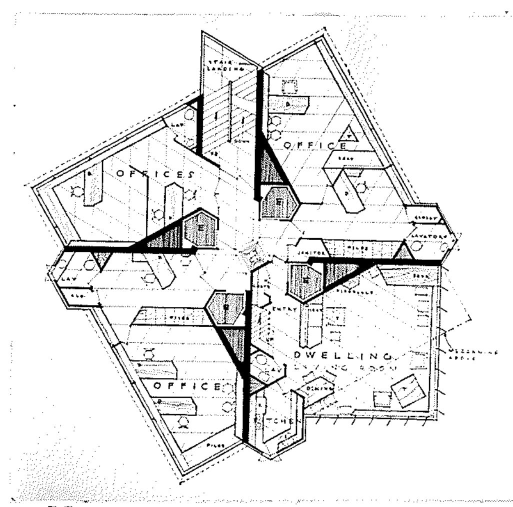

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Not only are these slabs the sole vertical structural elements of the tower they also contain both the mechanical risers and the elevator shafts. In addition to this, they also organize each level of the tower into its five major compartments - three office suites, one apartment suite, and the elevator lobby. Thus, with the exception of the fire stair, Wright has defined every aspect of the tower, on the supra-suite scale, with a single MULTI-purpose element.

As is evident in these examples the multi-purpose element is an especially efficient means by which the relative capability of a system may be augmented. But then this is to be expected in that the multi-purpose element results from the simultaneous occurrence of overlap and internal specialization,two accompanying characteristics of systems which previously have been shown to be efficient means by which the relative capability of systems may be augmented.

CHAPTER 4. SYSTEM AND ITS ENVIRONMENT

4.1 Environment

A system is a particular subset of the totality of all elements and relationships among elements which exist at any time. Thus in defining a system the totality of elements is divided into two mutually exclusive and exhaustive subsets; the system and its complement - all other systems and free elements which exist at that time. Aside from membership or non-membership in the system the division of the totality creates an important distinction as to the nature of the elements or more precisely to the relationships among the elements. "External" relationships are those between elements of the system, on the one hand, and its complement, on the other. All other relationships whether they be solely among the elements of the system or solely among the elements of its complement are "internal" relationships. On this basis a further distinction as to the elements themselves can be made. Elements defined by relationships which are solely internal are "internal" elements while elements defined by relationships which include external relationships are "boundary" elements. Given this distinction as to the nature of elements the meaningful environment of any system can be defined as all of the boundary elements which are not members of the system. The environment of a system consists of all those elements which act upon, or are acted upon by the system.

Obviously consideration of any system must necessarily include its environment. To neglect the system's environment is to disregard relationships (between the boundary elements of the system and the environment) which are no less significant than the internal relationships of the system. For example, in the launching of a self-propelled missile, the system, the boundary elements of which are the surface configuration and thrust of the missile, makes sense only in the context of the physical forces of the air resistance and gravity of the earth. A system and its environment are complementary parts in any consideration.

As a system is an abstraction so is its environment. In architecture, where totally different kinds of characteristics can be represented as systems, a building exists in accordingly different kinds of environments. As a material system a building is a utilitarian artifact which exists in an environment of physical stresses. As a phenomenal system a building is a work of art in which the observer as well as the building is part of the system. Thus the environment is not only the sensory context of the building, the character of its surroundings, but also the cultural history which is the conceptual frame of the observer.

An environment is defined with respect to a system and hence is limited by that system. An element which lies outside of the sensitivity of a system does not have the possibility of meaningfully interacting with the system and consequently cannot be part of its environment. For example, for a mosquito the human environment of symbols simply does not exist. Similarly the ability to appreciate music is limited by the sensitivity and knowledge of the individual listener. Some people appreciate music mostly on the sensuous plane of pure feeling. Others appreciate music on the expressive plane of descriptive themes. Most musicians listen to music predominantly on its sheerly musical plane; that is, in terms of its systemic properties.[1]

However, as the environment of a system is limited by the system, so too, a system is limited by the environment in which it exists. Incompatibility between a system and its environment can result in devaluation or even destruction of the system. For example, most "mobile" homes are devalued in that, except for transportation from the factory to a permanent site, their inherent mobility is never utilized. (The fact that a mobile home is generally purchased because of its low cost which is a function of the process by which it is produced is entirely beside the point in this case.) Similarly, a man working on an assembly line is devalued for he is generally performing a mechanical task in which

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[1]Aaron Copland, "How We Listen". pp. 94-102.

much of his human complexity has been shut out. He has been dehumanized. However in those instances where the system-environment incompatibility is so profound that no reconciliation is possible the system is not just devalued, it is destroyed. The extinction of animal species is a case in point. Among artifacts the obsolescence of the horse-drawn coach, the clipper ship, and the one room school house are also examples.

4.2 The System-Environment Division

The relationships between the boundary elements of the system and the environment are at least as significant as the internal relationships of the system. Thus the natural question arises as to why the boundary between the system and its environment should be drawn in any particular place. Is the frame of a painting part of the system or part of the environment? The boundary between a man and his environment may seem obvious but to Marshall McLuhan clothing is an extension of the skin. The fact of the matter is that the division of any context of consideration into system and environment is dependent upon the needs of the divider. Consider the case of a man driving in his car along a road. To the driver, he and the car constitute a moving system in which the road is the environment along which they are passing. However, to the mechanical engineer, who is concerned only with the internal workings of the machine, the driver like the road is an "outside" force; that is, part of the environment. And to the highway engineer the driver, car and foundation conditions constitute the environment in which the system of his concern, the road, must exist. Generally speaking the system is the set of elements and their relationships which are of primary concern, while the environment is the remainder of the elements and relationships which together with the system make up the totality of concern.

In many ways this division is purely theoretical. A system and its environment are mutually dependent; both must exist for either to exist. That is, together a system and its environment constitute a larger totality. Nevertheless, the division is useful, especially to the system designer who usually must work to an existing environment. Ideally, of course, upon materialization of the system, it and its environment should become one, a unity. Specifically the advantage of the division resides in the fact that as a system and its environment are complements in the context of concern they define one another in their boundary characteristics. The compatibility of a system to its environment depends solely on its boundary characteristics and hence systems of different internal orders but similar boundary characteristics can fit the same environment. This is the concept of equivalence in systems. In the building industry this concept is clearly exemplified in the practice of bidding "alternates". Here different building components are treated as equivalents without regard to their internal mechanisms, solely on the basis of their boundary characteristics. Their internal mechanisms although extremely relevant to their particular nature are irrelevant in detail to their environmental fit.

The converse of equivalence in systems which is equivalence in environment is the reason "environment" was defined as it was. Concern for a particular system requires consideration of only the boundary elements of the complement of the system. To design a structure an engineer need only consider the resultant stresses acting upon the structure not the component stresses of which they are the resolution. The environment of a system consists only of those elements which act upon or are acted upon by the system. This, of course, does not preclude considering the environment of a system as a system in its own right, but then, this is a different consideration.

4.3 Value

A system is defined by its relationships with its environment. Only to the extent that it maintains these relationships, its environmental fit, can the system maintain its essential nature. A system is not inherently good or bad, therefore. If the system maintains its environmental fit it is good, if it fails to maintain its environmental fit it is bad. Value in systems is solely a question of environmental fit.

For example, survival is evidence that organisms such as mammals are reasonably well-fitted to their earthly environment. That is, relative to the environment of the earth mammals are reasonably good systems. However on a planet, say, which is incessantly bombarded by projectiles mammals would rapidly perish -- their highly specialized and inter-dependent subsystems being unable to withstand the puncturing these projectiles would inflict. Relative to this environment mammals would be bad systems.

Similarly it is obvious that while the goat skin tent is a reasonably good housing system for the desert nomad its thermal characteristics would make it a bad housing system for the arctic nomad.

So too, while the eclecticism of nineteenth century revivalism made it a good system relative to the intense archeological interests of nineteenth century culture this same characteristic made it an extremely bad system relative to the revolutionary moralism of the early heroes of modern architecture.

This, of course, does not mean that the only value applicable to particular systems is environmental fit. Environmental fit is merely the only "systems value". Particular systems may be subject to other value criteria as a function of "what they are"; that is, their content. However a discussion of the content of systems is out of the terms of reference of this thesis.

4.4 Open/Closed Systems

A system is open or closed by virtue of its relationship to its environment.

The ideal experiments postulated by physical scientists in which no energies enter or leave a system are paradigm examples of closed systems. As a result of this isolation these systems are subject to the laws of thermodynamics which state that while the energy contained in any isolated system is conserved, its degree of organization is not conserved. The consequence of thermodynamics is the inevitable degeneration in the degree of organization of a system until an end state of equilibrium, in which there exists no organization, is reached. This final state is one of complete randomness and independence and hence is only nominally a system.

Open systems are not subject to this inevitable fate as they exchange energy and information with their environments.[1]

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[1]It has been suggested that the universe is a closed system and hence that open systems represent only local and illusory "contraventions" of the laws of thermodynamics. If this were the case the apparent increase in the degree of organization contained in these open systems would actually represent a decrease in the degree of organization of the universe as a whole and hence bring it more rapidly to its inevitable end. However, whether or not the universe is, in fact, a closed system is not known. In any case the time scale involved in this question is so great as to be beyond human comprehension.

Energy and information are distinctly different types of input.[1] Energy inputs, in whatever form, serve both to maintain a system and to energize it, making it ready to function. Information or signal inputs serve to inform the system of its environmental situation. Signal inputs are dependent upon some form of energy flow to act as a vehicle in their transmission. However this energy component is entirely subordinate to the information which it carries. For example, visual information is carried by light energy but whether what is carried is a meaningful image or a confusion of colours and shapes is indistinguishable from the point of view of energy.

Although the distinction between the two functions of energy inputs is not immediately apparent in familiar examples of open systems such as organisms it is very apparent in human artifacts. Organisms such as animals ingest high quality energy in the form of animal and plant matter and exhaust equivalent amounts of energy in the form of heat and material wastes but in a significantly reduced state of organization. In this process they maintain their material structure and also operate their numerous subsystems. In artifacts, however, maintenance of material structure and operation of the

[1] It is interesting that formal (mathematical) identity exists between the expressions of entropy (Second Law of Thermodynamics) and information. However, speculation as to the implications of this identity are beyond the needs of this paper.

various subsystems are distinct tasks which receive distinct forms of energy input. A computer, for example, is energized and made functional by an electronic energy source. However, its material structure can only be maintained by some outside agency which acts as an extension of the machine. This outside agency must introduce material substances in the form of parts to compensate for wear. This is the function of the automobile mechanic, television repairman, and building maintenance crew. In terms of maintenance, then, artifacts in themselves are closed systems; they wear out, and can only be maintained in a quasi-open state through the actions of some outside agency such as a human acting as an extension of the artifact; as the artifact is an extension of man.

Apparently the ability to maintain its own material structure is unique to what are conventionally called living systems. Non-living systems made of highly decay-resistant materials may appear to avoid the maintenance problems of closed systems. However, this is just a matter of viewing the system on a time scale appropriate to its substance. From the human perspective, though, these decay-resistant materials may be considered relatively self-maintaining or more correctly maintenance-free. "Diamonds are Forever". Nevertheless there is no necessary reason why systems could not be devised which would be self-maintaining in this sense. Whether they would be considered living or not is immaterial. Interestingly, medicine has made significant advances using the part replacement technique developed for artifacts. In many instances when a living system can no longer maintain itself due to failure of some subsystem the subsystem is replaced or reinforced by a mechanical or even alien living surrogate.

The distinction between living and non-living systems does not enter into the realm of intelligence, however. Intelligence, defined as the ability to utilize information (signal inputs), is becoming increasingly commonplace in human artifacts. Of course as a system exists in a particular environment its intelligence is relative to that environment or rather the nature of that environment's signal inputs. Electronic tapes can be just as real an environment as earth, sea and sky. The computer and airplane autopilot are common examples of artificial intelligence. Even such a generally dumb artifact as a building has an intelligent subsystem in its thermostatically controlled heating. Signal inputs and intelligence become increasingly more important to a system as its base of survival shifts from static independence to dynamic interdependence.

The extent to which a system is energized and maintained by energy inputs and informed by signal inputs is, in large measure, the extent to which a system can maintain itself. Energy inputs maintain its material being. Information inputs inform it of its environmental situation so that, energized by energy inputs, it can adjust and change in response to adjustments and changes within its environment. In this way an open system can maintain itself in a dynamic environment.

CHAPTER 5. BEHAVING: SYSTEM MORPHOSTASIS

The nature and even existence of a system is threatened by the internal and environmental stresses which act upon it. In order to maintain its threatened nature a system acts to obviate these stresses. The acts of a system, its behaviour, arise out of the interactions of its elements: Behaving is a manifestation of being, a response to stress.

5.1 State

Although the concept of state is properly within the discussion of being it is unique with respect to being in that it involves the dimension of time, the dimension of behaving. Indeed the full significance of the concept of state only becomes apparent in the relation of being to behaving. Thus it is used here to introduce the discussion of behaving.

As the nature of a system is defined by the relationships among its elements it follows that the configurations in which the system can exist are also determined by these relationships. For example, three squares which can be joined only at the corner can be joined in only two possible configurations.

The state of a system at a particular time is the configuration in which its elements exist at that time. Some systems, such as fossils, and crystals, the individual fixed structures common to most bridges, buildings, and furniture, and class status in feudal societies, exist in a single state for the length of their existence. However many systems exist in numerous states over time. A cactus blossom open to the cool of the desert night exists in a different state than when it is closed to the heat of the day. Similarly a business office exists in different states when its manager is chairing a sales meeting, dictating a letter to his secretary, or conferring with his tax consultant. Perhaps the system which exists in more states than any other, and hence the one to which the dimension of time is most critical, is the human mind which exists in as many states as it has thoughts.

5.2 Variability

The behavior of a system at a particular time, as it arises from the interactions of the elements of the system, is determined by the particular configuration in which the elements exist; that is, the state of the system, at that time. Consequently the variability of potential behavior of a system is determined by the number of states in which it can exist.

The behavior of a system which can exist in but one state is necessarily invariable. This is the static behavior of a structure which must simply withstand the loads bearing upon it. It is the compulsive behavior of Pavlov's dogs which salivate automatically in response to the sound of a bell. It is also the constant behavior of the sign post which passively awaits observers. In each case no repertoire of acts is available from which to select behavior in response to the situation. A system of single state and consequent invariability of behavior therefore must cope with the situation by the strength of its response rather than the appropriateness of its response; by force rather than fit.

The behavior of a system which can exist in more than one state may be variable. Thus in response to each kind of situation the system may choose among different strategies; the number dependent upon the number of states in which it can exist. This is the dynamic behavior of a football team which seeks to gain yardage by utilizing a variety of plays, permutations on the different configurations which various specialized players can assume in conjunction with different ball handling procedures. Animal behavior varies over a repertoire of acts which increases in proportion to the intelligence of the animal. There are numerous ways in which most animals can meet their need for nourishment, witness especially the diet of man! Even many of man's material artifacts behave variably. The swing-wing jet adjusts the configuration of its wings so as to maintain an optimum aerodynamic shape with respect to its velocity. In each case a repertoire of acts is available from which to select behavior in response to the situation. A system of multiple state and consequent variability of behavior may therefore cope with a situation firstly by the appropriateness of its response rather than the strength of its response, by fit rather than force.

Materially buildings behave variably in minor but nevertheless significant ways. Typically doors, windows, blinds, curtains, awnings, and furniture can exist in a few or many different configurations. In certain building types a more formalized attitude toward variability has developed. This attitude is manifested in office design by modular partition and furniture systems and, more recently, by "office landscape"; in hospital and laboratory design by accessible and adjustable mechanical systems; and in school design by open area planning. However in terms of major adjustments of a short term nature buildings, by and large, are essentially invariable.

This static nature of most buildings has been felt, increasingly over the last several decades, to be an inadequacy. Contemporary efforts in this regard have been directed mainly toward the design of "building systems". These systems are kits of parts, somewhat after the model of the material aspects of the vernacular house as developed in 17th and 18th century Japan. To date, however, these kits of parts are such that they can be assembled into only minimally systemic buildings. The variability which they apparently have is a function of the independence of the part rather than the dynamism of the whole. Perhaps the most widely known example of the "kit of parts" building is the school building system developed by the Educational Facilities Laboratory in California (SCSD).

However there is another approach to variability in buildings which traces its lineage back to the cave. This approach is embodied in its extreme form in contemporary architecture in the work of Mies van der Rohe, one of the first modern architects to concern himself with the implications of the variability of 20th century life. To Mies, in the uncertainty of contemporary times, it was naive if not blatantly irresponsible to design to the limited criteria of the specific intent. Rather Mies chose to design a "universal space", a space which could be anything its inhabitants chose to perceive[1] it to be.[2] Thus a space was variable as a function of the adjustment of the perception of its inhabitants rather than just of the adjustment of its physical parts. Of course, it is debatable as to whether or not Mies actually was able to design the universal space of which he

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[1]"To perceive" as used here is obviously other than simply "to sense". Perception involves the ordering of sensation, an act of understanding.

[2]The more radical aspects of this concept will be considered in the next chapter, Becoming: System Morphogenesis.

spoke. Nevertheless as is evidenced by the baronial halls of feudal Europe and the longhouses of the Iroquois every aspect of (domestic) life can be conducted within the confines of a simple envelope just by an adjustment of the perception of the inhabitants.

Variability by adjustment of perception is more profound than just an approach to planning, however. It is also an expression of the inherent variability of phenomenal systems such as the genius of a place. Obviously as this character of place arises from the interaction of the building and its inhabitants it is as variable as is the inhabitant's perception of the building. Thus any building may be a multiplicity of "places" even to an individual inhabitant. That this multiplicity of perception is an active aspect in every good work of art is evident in the debate which it arouses. A good work of art has an inherent ambiguity and multiplicity of aspect which engenders many interrelated and even contradictory perceptions, both in terms of what it is and in terms of the significance of what it is. That the architect's perception of his own building is often at odds with that of the public is confirmation of this. Indeed if it were not for this ability of the inhabitant to adjust his perception of a building to his own needs it would be difficult to explain the continued potency of the monuments of long extinct civilizations.

Needless to say the genius of a place is also variable as a function of adjustments of the physical parts of the building.

Even physical variations outside of the building affect its character. Thus the daily weather; the regular passage of day to night to day; and the yearly cycle of the seasons cause variations in the mood of a place.

Of the physical adjustments actually of the building perhaps the most common are the variability of arrangement in furnishings and the variability in the pattern of artificial illumination. Simply by the arrangement of chairs in a room many different places can be created. An island of intellectual communion is created by the "round-table" organization of the seminar. The asymmetry of the formal lecture is initiated simply by the subordination of the chairs to the lectern. The informality of a lounge is set by the grouping of its furnishings. Similarly simply by a change in the lighting of a theatre the atmosphere changes from one of public gala to private fantasy.

By virtue of its behavior a system exists through time; its temporal nature a function of its variability. From one state to another, opened to closed, public gala to private fantasy, architecture is meaningfully measured in time.

5.3 Stability

A system is generally subject to stresses both from within as a result of inherent inconsistencies or incompatibilities among the relationships of its elements or as a result of its energy or information needs; and from without, as a result of stresses acting upon it from the environment. A system which behaves so as to maintain its essential nature in the face of these internal and environmental stresses is said to be stable. Obviously, stability is essential for the continued existence of a system.

A system can maintain its stability only if its variability of behavior equals or exceeds that of its environment for only then can it respond to all of the stresses which may come to bear upon it.[1] Thus, for example, one light or two would not be good enough for Paul Revere today for the British might come by land, sea, or air. Similarly, a theatre system capable of thrust and proscenium stages must eventually be found inadequate by a theatre company which finds it necessary to utilize theatre-in-the-round as well as thrust and proscenium stages. The possible environments in which a system can be stable is limited by the variability of its behavior - the greater the variability the greater the range of environments.

As a product of the behavior of a system, stability can only be understood as the result of the interactions of its elements. The stability of an arch, for example, is a function of the interdependence of the individual rocks - remove one and the whole arch

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[1] Ashby's Law of Requisite Variety - see W. R. Ashby, "Variety, Constraint, and the Law of Requisite Variety".

collapses. The stability of a boat under sail results from the dynamic interaction of the moments (lever forces) due to wind in the sails, water on the centerboard, and displacement of ballast. An unanswered change in any of these factors may cause the boat to capsize. Similarly the homeostasis of the human body is a function of the interactions of its parts. For example, the constant temperature of the body is maintained by proportioning the production of heat which necessarily accompanies all organic activity, and the loss of heat so that the net gain or loss in temperature counteracts the temperature stress of the environment. The variables involved in striking this balance concern both the rate of heat loss and the rate of heat production. The rate of heat loss is variable as a function of the volume of blood flowing near the body surface, and the rate of evaporation of body moisture, both on the skin and in the lungs. The rate of heat production is variable as a function of non-essential organismic activity, some of it automatic such as shivering, and the rate of metabolism within the body. Thus by manipulating these mechanisms with respect to one another the temperature stress of the environment, whether it be toward raising or lowering the body temperature, can be counteracted and the constant temperature of the body maintained.

Stability can only be understood as a product of the interactions of the elements of a system, a condition of the whole which results from the interactions of the parts. Stability is a singularly systemic property.

5.4 Equilibrium

It is an axiom of natural science that all systems are in flux until they achieve a condition of stability. Thus in order to exist in a single state over time, to behave invariably, a system must be stable. Equilibrium is the stability of systems of single state.

Systems which behave invariably are systems whose performance-eggs are in a single behavioral-basket; they may cope with stress only in the strength of their response. There is no intelligence or selectivity in this behavior, just endurance. This, of course, is not to say that systems which exist in a single state are capable of only one act, one response to all types of stress. As there are numerous types of stress invariable behavior may involve numerous types of response; however, for each type of stress there can be only one response. For example the human behavior which originates in the attitude that "there is only one way to do ... something", like the compulsive behavior of Pavlov's dogs, is invariable. Different types of tasks may be accomplished in different ways, but each type of task may be accomplished in only one way.

Thus, as the stability of a system is dependent upon the variability of its behavior equaling that of its environment, equilibrium is possible only in an environment of invariable behavior. Gravity is such an environment. Consequently structures which must simply resist the force of gravity require no variability of behavior. Of course most structures are also subject to secondary environmental forces of variable behavior. These variable forces are accommodated, however, simply by designing the structure on the assumption that they exist at their greatest value at all times. Hence, while the structure may be overdesigned with respect to these forces at most times, it need not be variable.

Nevertheless environments are rarely invariable, especially environments of which man is an essential part, and so systems of invariable behavior are severely limited in their applicability. For example in an auditorium designed specifically for a particular performance invariable acoustic behavior is clearly adequate. However in the more typical case of an auditorium in which a variety of performances and performing arts must be accommodated acoustic behavior comparable to that of the particular-performance auditorium is possible only through variability of behavior. More commonly, while individual tables and chairs may be invariable the relationships between these individual furnishings is generally highly variable. Consider the simple desk-chair relationship, let alone the wide variety of interpersonal situations which are reflected in the arrangement of furniture. Thus, while elements within a furniture system may be invariable, the system, as a whole, must be highly variable.

5.5 Morphostasis

Unlike systems of single state which must simply bear up under internal and environmental stress, systems of multiple state can obviate stress by assuming that particular state or sequence of states most appropriate to the situation. Systems which behave variably maintain their stability by fit rather than force. Morphostasis is the stability of systems of multiple state.[1]

In order to select the state or sequence of states appropriate to its continued morphostasis a system firstly must have information as to its situation, and secondly must have some mechanism which on the basis of this information is capable of selecting an appropriate course of action.[2] In short, morphostasis

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[1]Properly morphostasis is the generic term applicable to all forms of system stability including equilibrium. However, equilibrium is used here to designate the stability of systems of single state as these systems are treated as a special case of systems of multiple state.

[2]As information is essential to the maintenance of morphostasis only systems open to signal inputs can be morphostatic. Also as energy is expended in dynamic behavior only systems open to energy inputs can be morphostatic. Consequently only open dynamic systems can be morphostatic. In any case by virtue of the second law of thermodynamics closed dynamic systems must eventually become static.

is dependent upon some form of systems intelligence, whether it be reflexive or reflective.

Central to the nature of this intelligence is the nature of the information it utilizes. Specifically the information essential to morphostasis is information, commonly termed "feedback", of the relation between the stresses acting upon the system and the behavior of the state it is in. If the behavior is such that it tends to reduce stress, morphostasis is reinforced. Consequently feedback is positive and the system will tend to remain in the state it is in. If the behavior is such that it tends to increase stress morphostasis is jeopardized. Consequently feedback is negative and the system will tend to assume a different state, one which will counteract the results of the previous, detrimental state. Thus by continually assessing its behavior in relation to internal and environmental stress the system is able to adjust so that the stresses acting upon it are minimized.

Morphostasis is essential to the continued existence of every living system. In order to maintain life stresses due to energy needs, changes of environment, and predators must all be kept in check. Even the most primitive of organisms, algae for example, change state in response to stress, carbon dioxide and organic nutrients from the water and solar energy from the sun. Ascending the evolutionary ladder morphostatic mechanisms become more diverse and complex. Man, the self-proclaimed summit of this ladder, not only manifests a most finely tuned homeostasis of body which is essential to the continuance of his life, but also manifests a unique morphostasis of mind which is essential to the continuance of the quality of his life.

Morphostasis is also essential to the continued existence of all supra-living systems; systems whose elements are living systems. The prey-predator couple in which the numbers of both prey and predator are mutually regulatory is a well-known example of morphostasis common to ecosystems. Systems of men, social systems, are also dependent upon morphostatic mechanisms for their continued existence. Indeed this evident dependence on morphostatic mechanisms is so great that many of these systems have clearly defined subsystems whose express purpose it is to act in this respect. These subsystems are known as governing bodies. The archetypical governing body is, of course, the state which acts so as to reduce pressures brought to bear upon it by various interest groups.[1]

Morphostasis also exists among systems composed of man-machine couples. For example in travelling by automobile the driver acts as an intelligent subsystem of the couple, a morphostatic mechanism which regulates the behavior of the automobile.

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[1] The justness of any society is dependent upon how representative these pressures are of the elements which constitute that society.

However morphostasis also exists among some man-made systems which contain no living subsystems. These systems, which contain intelligent subsystems called servo-mechanisms, have been the source of great excitement since 1950. Indeed servo-mechanisms have been hailed as prototypes of the second industrial revolution, the cybernetic revolution. The reason for this excitement is the realization that machine morphostasis is the last step in removing man from all those forms of mechanical activity which is necessary to him, but with which he would rather not concern himself. Contemporary examples of servo-mechanisms range from the household thermostat to the airplane auto-pilot. The essence of these mechanisms is that once performance standards have been established the system will perform to these standards regardless of the pattern or timing of stresses which act upon it. The auto-pilot, for example, once set will maintain a straight and level course automatically correcting any displacement in the roll, pitch, or heading of the plane. In fact the auto-pilot is also capable of making pre-planned course changes. Theoretically, once initiated, any mechanical behavior can be accomplished entirely without human involvement.

CHAPTER 6. BECOMING: SYSTEM MORPHOGENESIS

The internal and environmental stresses which act upon a system may change. To maintain its existence the system must change accordingly; it must adapt to its new situation. With each change, each becoming, being and behaving are defined anew: being and behaving are a function of becoming.

6.1 Change

There are three types of change within a system by which it can adapt to changes in the internal and environmental stresses acting upon it: potential relationships among the elements of the system may be actualized, existing relationships among the elements of the system may be changed, and elements may be added to or subtracted from the system.

The first source of change within a system, the actualization of potential relationships among its elements, is the tying of some of the "loose ends" which exist in all systems. For example, as a child matures his bodily movements become more coordinated - a process in which potential relationships in the control of individual muscles are actualized.

So too, in many cities while the urban core and suburban municipalities are functionally interdependent no governmental relationship exists between them. This often results in great tax inequities which threaten not only the unfavoured partner, the core, but the whole as a consequence. In order to rectify this inequity a governmental relationship may be defined, amalgamation being its extreme form.

However, change as a result of the tying of loose ends finds its paradigm in the realm of art. The source of the perpetual fecundity of art lies in the continuous unfolding of previously unperceived relationships which not only color and shade the existing multiplicity of juxtaposed meanings but also, in the perception of an original mind, give rise to entirely new meanings. By its very nature, art is as changeable as the mind that perceives it.

The second type of change within a system, the change of existing relationships among its elements, is a change in the very nature of the elements, for, by virtue of the defining role of the relationships among the elements of a system, to change the relationships is to change the elements and conversely to change the elements must be to change the relationships.[1] This type of change may be initiated from within the system as when a society changes its laws in accordance with its changing values or when a person's perception of a place changes as a result of a new understanding of

[1] see section 3.1 "Elements" for a discussion of the defining role of the relationships of an element.

the relationships of its parts and their relationship to him. Even some systems which are independent of human intelligence are capable of internally initiating this type of change. The chess-playing computer, for example learns from its errors correcting the relationships within its memory banks.

In systems lacking this kind of reflective intelligence changes of the existing relationships of its elements must be initiated from without. The material renovation of buildings is a classic example. Here man, an intelligence outside of the system, must change parts and the relationships among the parts as his needs of the building change. Of course as intelligent machines exist which can actually change their organization, not just their state, it is conceivable that servo-mechanisms could be developed which could initiate material change within buildings.

The third type of change within a system, the addition or subtraction of elements has implications beyond itself for it involves the addition or subtraction of relationships with other elements within the system and hence has implications on the nature of these elements as well. For example, adding a support to a system of supports carrying a continuous load causes the load carried by every individual support to change. Introducing a new person into a group causes each member of the group to enlarge his set of relationships and may even change the social order of the group so that a great many other relationships of each member are changed in the process.

A change in the number of elements may be simply a change in the extension of a system. More area is required so several structural bays are added to a building. In order to utilize accumulated capital a company expands its operations. Due to a lack of supply ability an army is forced to sacrifice its outer-most battalions. Also a change in the number of elements may be a change in the connections within a system. This is the case where elements act as links between different parts of the system. The construction of a bridge, for example, connects separated parts of the street system of a city. Similarly long distance lines connect the telephone systems of different communities.

However, changing the number of elements of a system rather than just changing the range of its abilities may change the very nature of its abilities. Thus the addition of a specialized subsystem, sight to a blind man, for example, radically changes the behavior of which the man is capable. Similarly the introduction of mass high-speed public transportation in the urban core of a city changes not only the means by which people move from one part of the core to the other but also changes the scale and organization of the city as well.

It is evident that change within a system is a highly ramified occurrence -- a change in part having implications throughout the whole.

6.2 Self-Amplifying Change

Sometimes a change within a system is not so significant in itself but rather is significant for the process of self-amplifying change which it initiates. This is the process represented by the exponential curve, the vicious cycle, the inflationary or depressionary spiral, escalation and compounded growth or decay. The mechanics of self-amplifying change are basically simple: A change is made within the system. This change is such that the feedback which the system receives of its new environmental situation induces increased additional change within the system which in turn induces even more change within the system and so on. In this way the initial germinal change initiates a self-amplifying process of greater and greater change.

Population growth is a paradigm example. In a constant population the rate of births equals the rate of deaths. However if these rates are changed so that there are more births than deaths the population will increase. Given the maintenance of this greater rate of births than deaths each generation will be a certain proportion larger than the previous generation. In other words each generation will see a greater increase in population than the previous generation. The change in population is self-amplifying.

Of course, once the process of self-amplifying change has been initiated it does not follow that it is uncontrollable or irreversible. Indeed the process itself has inherent limits. Not only is the population growth limited by the obviously finite ability of the world to sustain life, there also seem to be critical densities, at least among non-human populations, at which the process breaks down. Within these inherent limits population growth can be controlled simply by manipulating the relative rates of births and deaths. Thus the fact that this process of change feeds upon itself, is self-amplifying, does not preclude that it can be controlled.

Self-amplifying change may be initiated by any of the types of change previously discussed. The "breaking" of a code provides an excellent example of the self-amplifying process which can be initiated by the actualization of potential relationships. Once an initial relationship is defined; that is, the "key" to the code is discovered, the remainder of the relationships which make up the code rapidly fall into place. Thus with the discovery of the Rosetta Stone the meaning of Egyptian Hieroglyphics was readily deciphered.

A change in the relationships within a system, a change in the elements of the system, may also initiate a process of self-amplifying change. Thus the renewal of a degenerated urban area is often sparked by an initial germinal project. The effect of the introduction of this project is to attract a few more projects into the area. These additional projects further enhance the area as a site for development so even more projects are attracted to the area and the process of self-amplifying renewal is underway. Of course, the reverse of this process of renewal may also occur. An urban area may be subject to self-amplifying degeneration. Initially only a small part of the area may be misused or allowed to decay. Unfortunately the degenerated condition of this part devalues the neighbouring parts within the area and so they, too, may be allowed to decay; the original occupants probably moving to a more suitable area. This further devalues the area, and so on, with the result that a vicious cycle of devaluation rapidly causes complete degeneration of the area.

In a similar manner the addition or subtraction of elements may also initiate a process of self-amplifying change within a system. Thus the growth of a city is initiated by the establishment of some community facility; a fort, store or transportation terminal, for example. Because neighbouring facilities tend to be mutually reinforcing as a center for patrons, even if they offer competitive services, this facility may become the nucleus about which further growth develops. If this is the case, with the addition of every facility the centre becomes more attractive as a site for further growth and so the by now familiar process of self-amplifying change proceeds. In fact, this process of growth is self-amplifying not only in the sense that with every addition to the center its proclivity to further growth is increased but also in the sense that its relatively greater proclivity to growth inhibits the growth of lesser centers in the region -- its growth is self-amplifying in a relative as well as absolute sense. Thus depending upon the growth potential of the region the nucleus may grow to be a village, town or even city.

6.3 Emergence

Inherent to every system are limits in the extension of its abilities beyond which further extension necessitates an extension of its multi-level order.

Thus the emergence of a governing supra-system is necessitated by an increase in the complexity of interaction among systems which is beyond the ability of each individual system to manage. For example while aircraft were few and slow the activities of taking off and landing could be managed by visual or radio communication among the individual pilots. However, as the numbers and speed of aircraft increased it became impossible for each individual pilot to maintain appropriate behaviour with respect to all of the other aircraft. At this point it became necessary to integrate the activities of the various individual aircraft through the means of an air control system.

The recent history of environmental control demonstrates a similar emergence of a governing suprasystem. Thus at the turn-of-the-century temperature, humidity, and ventilation were dealt with more or less independently: temperature was controlled by stoking or damping the furnace and raising or lowering shades and awnings, humidity might be dealt with simply by putting a pan of water in front of a radiator, ventilation was dealt with by the opening or closing of windows. Today, however, much greater environmental control is possible because temperature, humidity and ventilation have been integrated by a cybernetic supra-system into what is termed "air-conditioning".

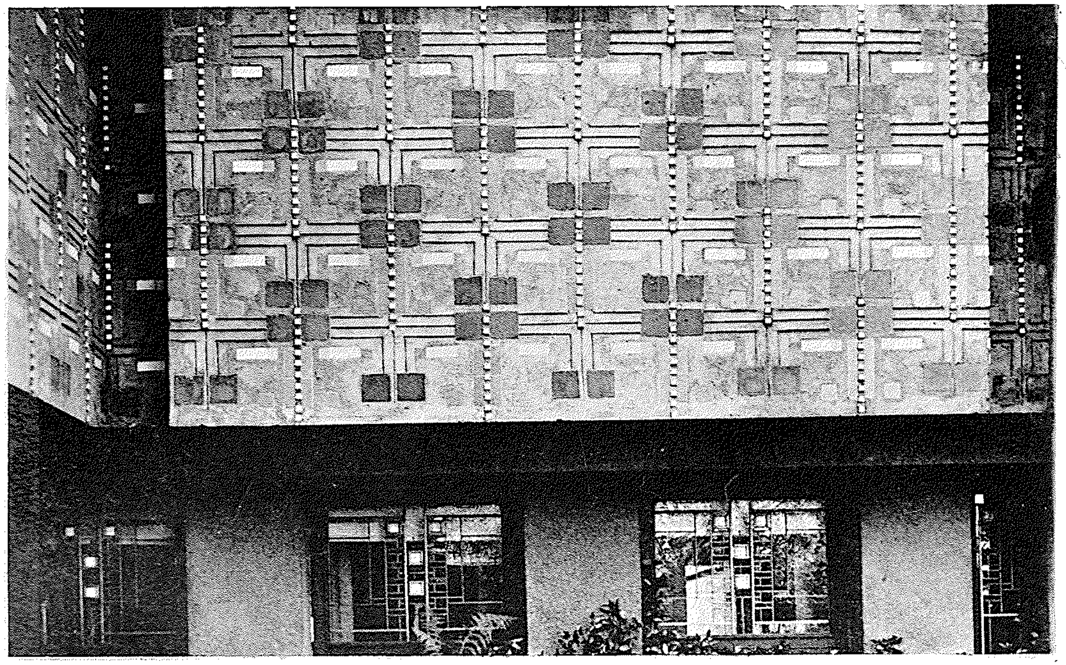
The emergence of subsystems is necessitated by an elaboration of behaviour beyond that possible at the level of the system. Subsystems are an elaboration of the abilities of a system within the existing framework of the system. For example the evolution of the automobile has been much an exercise in elaboration; the emergence of subsystems. In the first automobiles the fundamental parts, the power train and body, already existed. From this point on development, although increasing the gross abilities of the power train, conspicuously has been concerned with "smoothing out the bumps". This has meant the development of such refinements in the power train as battery powered ignition, automatic transmission, hydraulic steering and braking, pneumatic tires and shock absorbers. In the body development has taken the form of such refinements as windshield wipers and washers, air conditioning, power windows and seats, and even secondary entertainment systems such as radios, tape decks, and televisions.

Wright's Prairie Houses are also an excellent example of elaboration through the emergence of sub-systems. In these houses a theme is stated on the scale of the whole and then reiterated throughout the successively smaller scales of the parts. In this way the inhabitant's perception of the house is reinforced on every level of his experience. In the Coonley House, for example, this emergence of subsystems, and subsystems within subsystems, for the purpose of elaboration is especially evident -- "harmony spreads to every material of which it is made. Study will reveal that shapes in lead, in glass, in wood, in copper, in terra-cotta, in concrete are mirror-images, large or small, of each other and of the whole."[1] (12, 13)

6.4 Adaptation

Adaptation is the result of change within a system or

[1] G. C. Manson, Frank Lloyd Wright to 1910, p. 95



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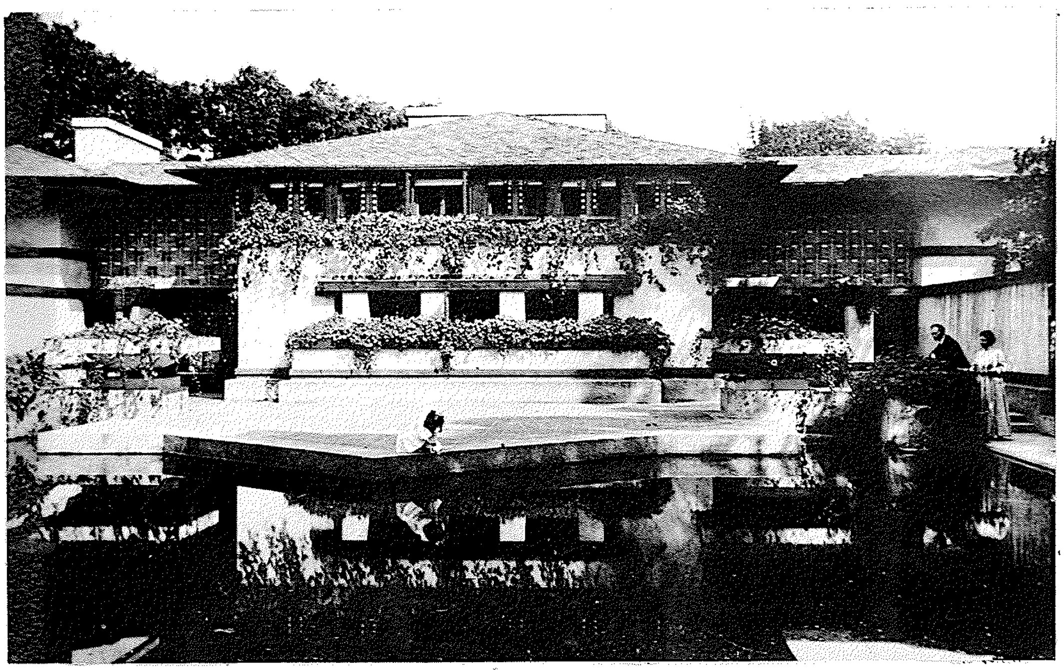

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system-type through which its existence is maintained in a changing environment. The types of change within a system by which adaptation is achieved have been considered. Therefore the question at hand is, By what means are these types of change utilized to achieve adaptation; both phylogenic adaptation - the adaptation of the system-type, and ontogenic adaptation - the adaptation of the individual system?

Within natural systems phylogenic adaptation is the result of chance variations among individuals within the system-type those of which are adaptive to the changing environment survive and propagate the type after their nature. This is the familiar Darwinian formula of chance variation and natural selection.

Ontogenic adaptation within natural systems occurs most importantly in the form of change in the information utilizing ability of a system -- learning. This change may involve the addition of new bits of information, the definition of new relationships among bits of information already acquired, or even, since all learning is not appropriate, redefinition of existing relationships which have been found inappropriate.

Of more interest is adaptation within man-made systems. Christopher Alexander has divided adaptation within man-made systems and system-types into two broad classes; those which are the product of tradition, a process of unselfconscious adaptations, and those which are the product of a designer conscious of his role as an innovator, a process of self-conscious adaptations.[1]

The implications of these differing processes upon the morphogenesis of the system-type are profound. Unselfconscious phylogenic adaptation, like natural evolution, is a very gradual process. Individual systems within the system-type may be varied, but, because of the strong direction of tradition, only in a few respects. Unsuccessful variations are not repeated while successful variations are emulated thereby molding the system-type after their nature. Of course, unlike natural evolution, these variations are based at least to a degree upon understanding rather than chance. Nevertheless the results are similar, successful adaptation, but only in a slowly changing environment.

Self-conscious phylogenic adaptation, on the other hand, because it is the product of a designer, who while he is undoubtedly conscious of his place in tradition is not completely ruled by it, tends to be less "inevitable". The designer in order to establish his individuality tends to become willful, his variations of the system-type involving the change of more variables than can be readily handled. Consequently adaptation becomes much more difficult

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[1] C. Alexander, Notes on the Synthesis of Form

to attain. However, this loss of ease is compensated in two respects. Self-consciousness releases man from bondage to tradition. Thus rather than watch his future unfold before him, the uncontrollable intersection of tradition and circumstance, man may actively participate in its direction. To be sure this is not a repudiation of tradition it is merely an awareness of the individual as an instrument for change. Also, self-consciousness in releasing man from the unmitigated control of tradition makes possible changes of the scope necessary to achieve adaptation in a rapidly changing environment such as our own.

The implications of the differing processes of unself-conscious and self-conscious adaptation upon the individual system while perhaps less profound than upon the system-type are a good deal more immediate. Unself-conscious ontogenic adaptation is basically a very straight forward process. Once a misfit between the system and its environment is detected the utilizer of the system simply makes the appropriate changes with the materials at hand. This directness curtails any possible ramifications misfit may have throughout the rest of the system keeping the problem of adaptation comparatively simple.

Self-conscious ontogenic adaptation lacks this type of directness. Here specialists using specialized materials are required to make any necessary adaptations. Consequently the utilizer of the system is hesitant to have minor adaptations made. Misfits are left to ramify through the system before the services of a specialist are acquired, the result being that adaptations are much more complex and thus comparatively more difficult to achieve.

Contemporary architects have made numerous attempts to develop more adaptability within the individual building. Mies van der Rohe's concept of universal space which was discussed with respect to the concept of change of state is more radically applicable to the concept of change of system. As it is possible to vary one's perception of a place it is also possible, in response to a changing environment, to change one's perception of a place. Thus as the Chicago Loop has developed over the last 20 years the individual Miesian tower has changed from a note of startling clarity in a sympathetic but somewhat more diffused symphony to a note of re-iteration in a symphony of staccatoed emphasis.

"Universal Space" applies to adaptability within the material order of a building as well, of course. It is a statement of the fact that the function of a space can be determined by the attitude the utilizer of the space brings to it as well as by its physical definition. How workable this approach to change can be is evidenced by the Georgian townhouses of London which, over the decades, have changed from private residences to apartments to offices and schools without requiring significant physical redefinition within the major spaces.

By and large, however, contemporary architects have concentrated their search for greater material adaptability in the area of physical change. Surprisingly this search has resulted in but a single fundamental observation. The underlying concept, common to the numerous formulations for greater adaptability in buildings, is the ordering of the subsystems of a building in terms of permanence, the most permanent forming a matrix into which the less permanent are suspended. Thus the less permanent subsystems may be changed independently of the more permanent subsystems. Most familiarly this concept is expressed in terms of a large scale infra-structure into which various transient modules of differing function may be "plugged" depending upon the needs of the moment.

6.5 Revolution

The changes within a system which were discussed at the beginning of this chapter are essentially changes in detail, modifications on the scale of the subsystem. However, thēre is a limit to the extent of change possible within a system on the scale of on the subsystem. Beyond this limit further change necessitates a change on the scale of the system as a whole. This is a change in the fundamental nature of the system -- revolution.

Revolution may be necessitated by the addition of subsystems to a system. This is a consequence of, what Boulding calls, the principle of non-proportional change which states that as a system grows the proportions of its sub-systems and of its significant variables cannot remain constant. For example an increase in the linear dimensions of a system will increase its areas as the square and its volumes as the cube, of the increase in linear dimension. The consequences of this principle can be simply illustrated: In a system of surface-breathing, surface-minimizing circles the addition to the initial nucleus of one element of elements two through six is a matter of detail, a change on the scale of the subsystem. However, the addition of a seventh element necessitates a fundamental change in the nature of the system -- either its surface-breathing or surface-minimizing character must be changed.[1] (14)

Revolutionary changes after this manner occur commonly, almost without notice.

> "Architecture and biology -- two sciences which are much more closely related than might appear at first sight -- provide admirable examples. A one-room schoolhouse, like the bacterium, can afford to be roughly globular and can still maintain effective contact with its environment -- getting enough light and nutrition (children) into its interior through its walls. Larger schools, like worms, become long in relation to their volume in order to give

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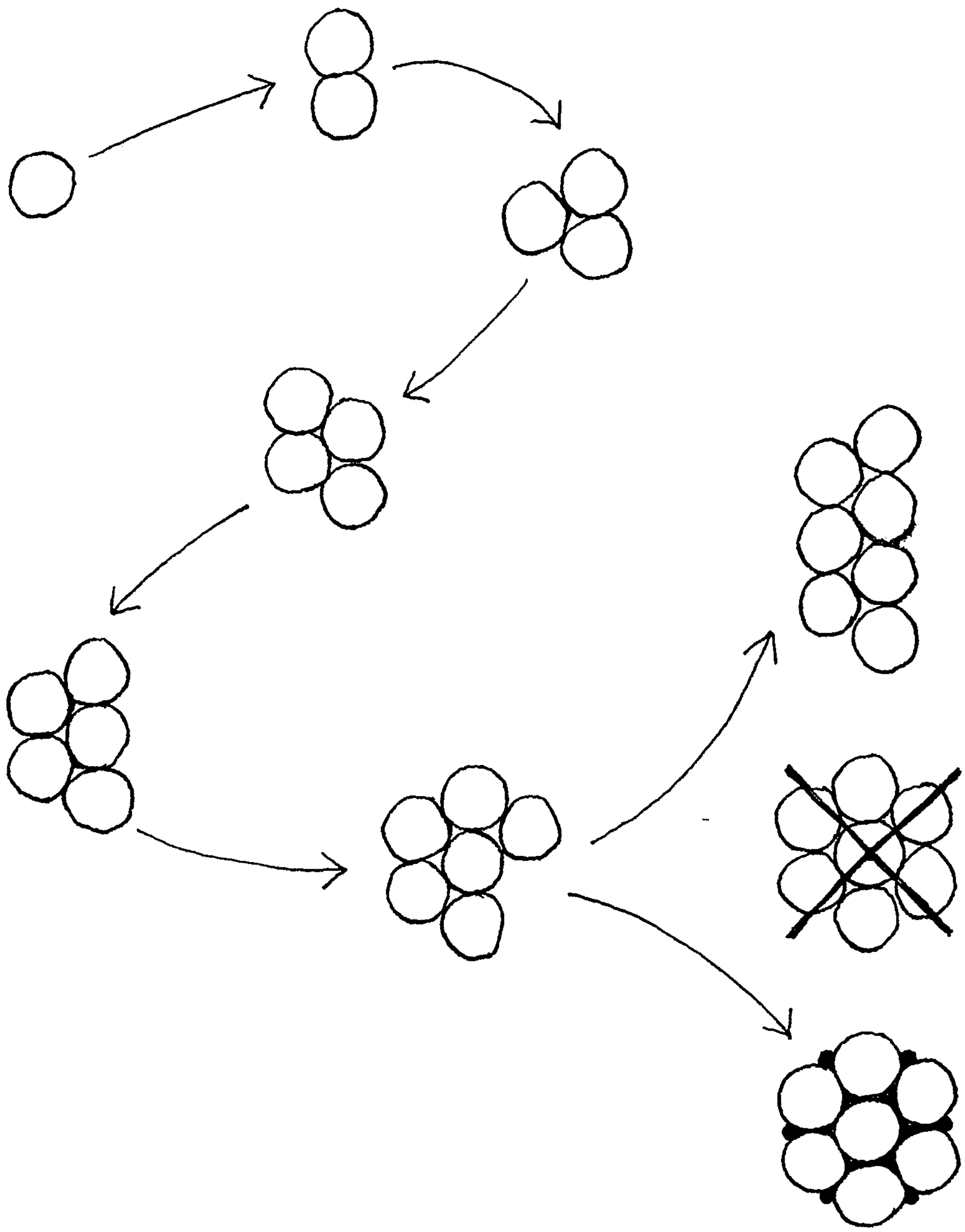
[1] It is evident from this discussion that Le Corbusier's plan for a Museum of Unlimited Growth is inherently unworkable or rather workable only within limits! Obviously the ability of the inhabitants of the Museum to comprehend its organization as well as their ability to walk its halls places limits on the ultimate size to which it may grow. Beyond this limit further growth would require a fundamental reorganization of the circulation system possibly including the introduction of a transportation subsystem.



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> every room at least one outside wall. Still larger schools develop wings and courtyards, following the general principle that a structure cannot be more than two rooms thick if it is to have adequate breathing facilities. This is the insect level of architecture (skin-breathing). The invention of artificial ventilation (lungs) and illumination (optic nerves) makes theoretically possible at any rate much larger structures of a "globular" or cubic type, with inside rooms artificially ventilated and lit, just as the development of lungs, bowels, nerves, and brains (all involving the extensive convolution to get more area per unit of volume) enabled living matter to transcend the approximately three-inch limit set by the insect (skin-breathing) pattern. In the absence of such devices further growth of the structure involves splitting up into separate buildings (the campus) [or some other organizational device] of which the biological analogy is the termite or bee colony."[1]

A more commonly perceived cause of revolution is the need for change in some of the elements/relationships within a system which can only be brought about by a change on the scale of the system as a whole. Revolutionary changes in thought, for example, are necessitated by misfits between existing theory and "reality" which cannot be resolved, even after numerous attempts, by a change in detail.[2]

In architecture, too, revolution is often necessitated by a need for change within the existing order of a system beyond that possible on the scale of the subsystem. Urban traffic congestion,

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[1]K. E. Boulding, "Toward a General Theory of Growth".

[2]T. S. Kuhn, The Structure of Scientific Revolutions.

for example, is a problem the solution to which, it is generally felt, does not lie within the adaption of existing transportation systems. Rather a change in the very nature of urban transportation, a change to a hierarchy of public transportation systems -- commuter trains, subways, and moving sidewalks, for example -- is needed. Similarly the solution to the problem of suburban sprawl (by those who see it as a problem) has involved a fundamental redefinition of the residential environment. This redefinition has taken such differing but equally radical forms as the universal dispersal of Wright's Broadacre City and the miniaturization of Soleri's Archologies.

A more pervasive manifestation of revolution in architecture occurs at the scale of the individual building. (On the scale of the City, this is not revolution but normal adaptive change.) Revolution within the individual building occurs when it is more "economical" to build anew rather than renovate the existing building. Examples are commonplace. However, carried to its logical extreme this attitude toward change results in a concept which, for many, attacks the very nature of architecture. This concept is one of impermanence, the individual building in a perpetual state of revolution -- "disposable architecture".

Of course, revolution is a much less assured process than adaption. Often revolutionary change brings with it problems more severe than those which necessitated the revolution. The general failure of the "bull-dozer" approach to urban renewal is dramatic evidence of this.

PART TWO

TOWARD ARCHITECTURE

The architectural entity is commonly thought to be a building or complex of buildings and perhaps such accompanying phenomena as pavements and plantings. To my mind this conception of what the architectural entity is, even though it reflects what architects spend most of their time designing, is too narrow. The essence of architecture is that it is the human habitat. As such not only buildings, groups of buildings, urban spaces, and gardens, and the cities which these make up, but also vehicles such as boats, automobiles and airplanes and even the natural landscape constitute architectural entities. The architectural entity is anything or rather any "place" which man inhabits.

The particular nature of the architectural entity will be discussed in this second part of the thesis. Specifically this discussion is of the systems which order the different dimensions of the architectural entity. Needless to say, these systems are abstractions, and as such are merely different views of a single non-decomposable entity.

CHAPTER 7. ARCHITECTURE AS A MATERIAL SYSTEM

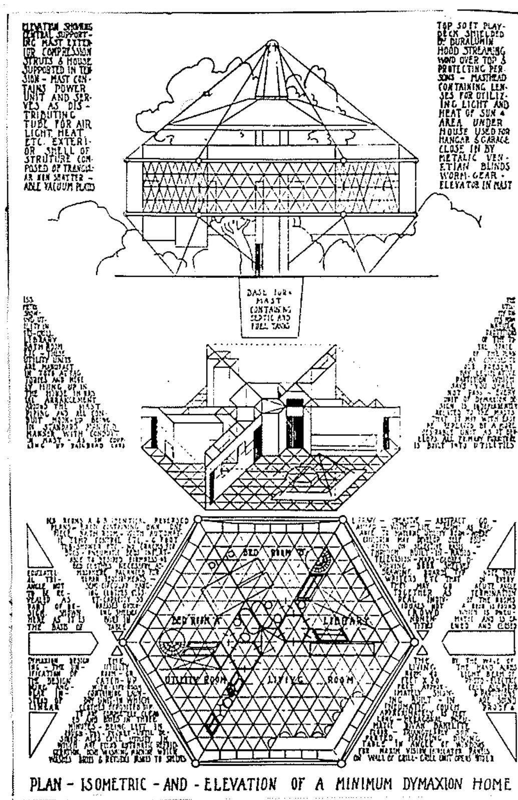
The relationships among the material parts of the architectural entity constitute its material order. Relationships with man may be included in this system but only man as an extension of the architectural entity, a servo-mechanism, or man as an environmental stress, a behavioral determinant. Relationships with man in his humanity, as inhabiter or creator, are not constituted within the system. In this sense the architectural entity, understood as a material system, is a machine.[1]

It is generally acknowledged that material concerns are of significance to the architect. Surprisingly, however, the architectural entity to which architects have addressed most of their energies — buildings — have seldom had important systemic properties within their material natures. Even in modern architecture where the increasing multiplicity of material parts, especially in the form of "engineered subsystems", would seem to have engendered this kind of concern among architects there is a conspicuous paucity of highly systemic buildings.

[1]"Machine" as used here is quite distinct from the usage of Le Corbusier in his famous statement, "A house is a machine for living in". Here "machine" is used strictly in its prima facia sense whereas for Le Corbusier "machine" had additional meaning as a symbol of the order of the universe - the house as a symbol of man living in universal order.

Buckminster Fuller's Dymaxion House of 1927 and Dymaxion Dwelling Machine of 1944 are unique examples of fully-serviced[1] buildings with important systemic (or in Fuller's terminology "synergetic") properties in that these properties were the primary concern of each project. The schematic Dymaxion House project (15, 16) is notable here in the interdependencies within the structural subsystem and between the structural and mechanical subsystems. The structural subsystem is an early example of Fuller's principle of tensegrity - the interdependency of discontinuous compressive members and continuous tensile members. In this case the isolated compressive members are the central mast and two hexagonal perimeter rings. These compressive members are "tied" into place by continuous tensile members in the form of suspension cables, guys, and floor structure. The structural and mechanical subsystems are interrelated in that the foundation serves as a housing for the septic and fuel tanks while the central mast serves as a service riser. The more studied Dymaxion Dwelling Machine project (17, 18) is notable in the special concern given to the interrelation of structural and ventilation subsystems. Here the structural members and shell were so formed, while retaining their own logic, that "the external air

[1] As opposed to simple envelopes such as the Geodesic dome, Candella's shells, or Frei Otto's tents.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PLAN - ISOMETRIC - AND - ELEVATION OF A MINIMUM DYMAXION HOME

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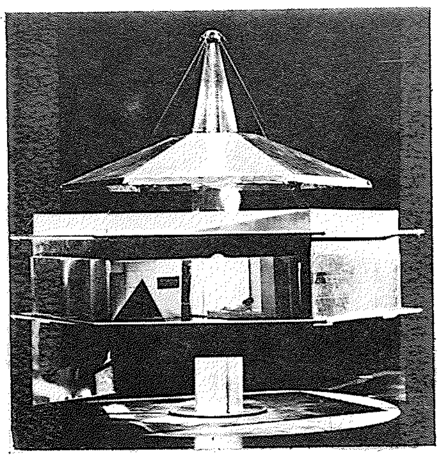

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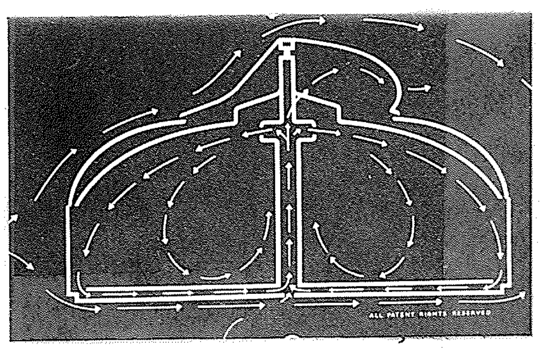
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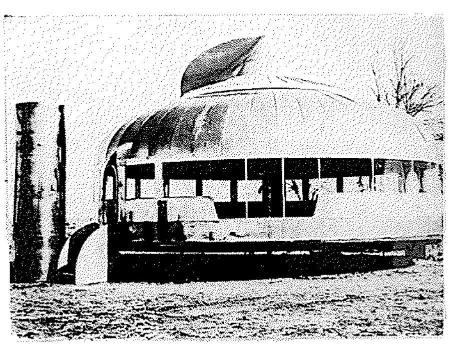

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flow, travelling its greatest distance over the top of the structure, created a vacuum drag at the ventilator, which in turn dragged the internal air flow pattern". "The incoming air was drafted upward through the large cylinder" (of the central mast). "Exhaust air pulled from the rooms", by way of the gratuitous ducting of the floor channels, "was drafted upward through the smaller cylinder" (of the central mast). "Thus the incoming air was never polluted by the exhaust air, even though the exhaust air lost its heat through the metal baffle to the incoming air".[1] Although less encompassing than the first, this second project is an especially graphic example of Fuller's ability to see different material subsystems in terms of their relationships to one another.

Frank Lloyd Wright was much concerned with the material order of his buildings, although not so exclusively as was Fuller. Unity Temple of 1908 (19), for example, exhibits interdependencies among its circulation/seating, lighting, structural, and mechanical subsystems. The point of departure of Unity Temple is a square plan.[2]

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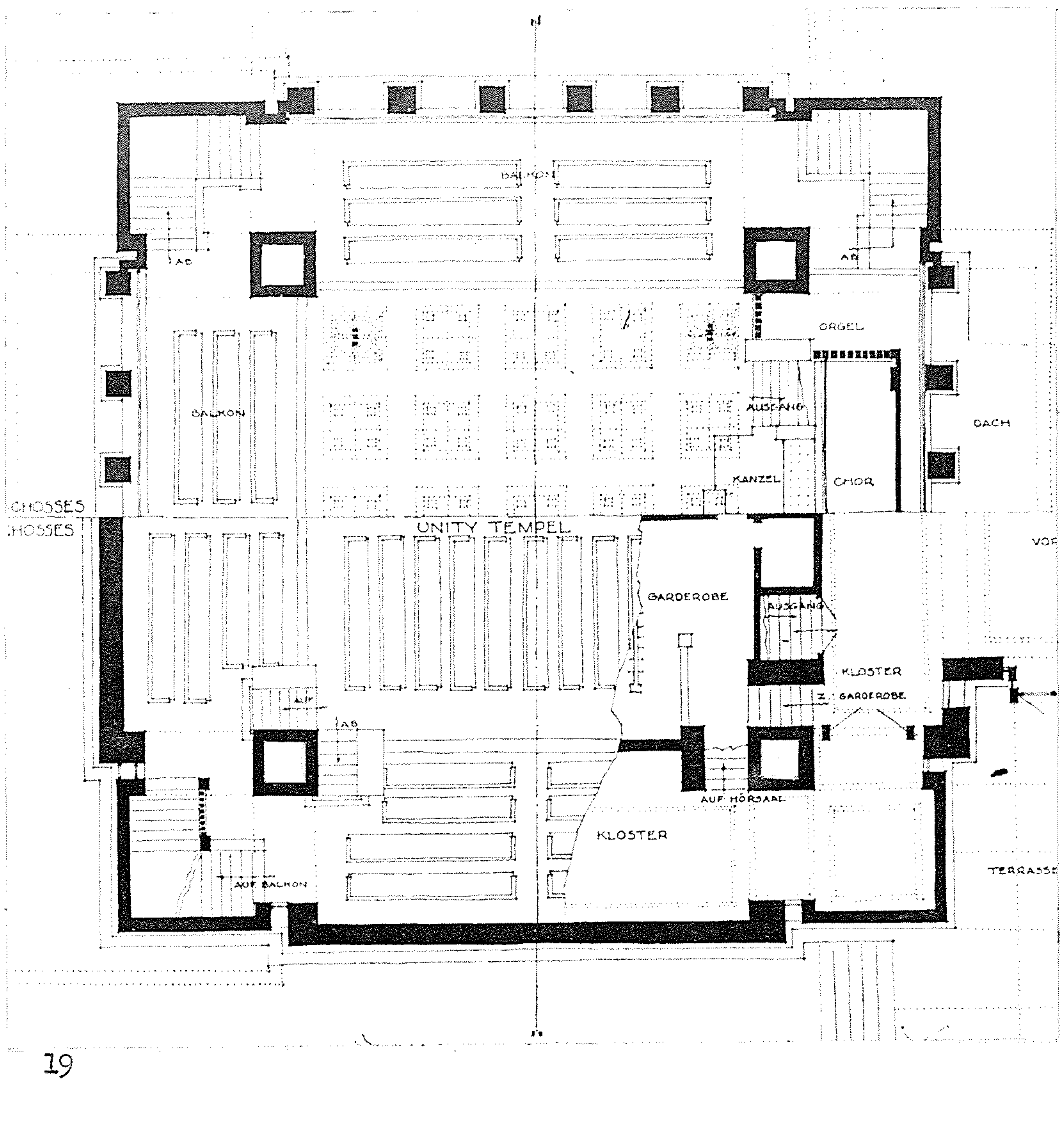
[1]R. W. Marks, The Dynamxion World of Buckminster Fuller, p. 123.

[2]There is something in Wright's work which may lead to confusion with regard to the material order of the architectural entity. This is the rigorous use of a geometricizing order -- "compositional rigorism". Compositional rigorism is not necessarily to material ends. Indeed as is evident in some of Wright's work especially that which is organized on a 30·/60· grid, compositional rigorism may even be questionable materially. Rather a strong geometric order is a characteristic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VOR
GARDEROBE
AUSGANG
KLOSTER
Z. GARDEROBE
AUF
AB
AUF HÖRSAAL
KLOSTER
TERRASSE
AUF BALKON

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Inscribed within this square is a greek cross, the points of intersection of which are demarcated by four vertical elements. These vertical elements thus define the nine different areas in plan within which the various parts of the circulation/seating subsystem are disposed -- stairs in the four corner areas, major seating in the central square, balconies and cloister on the different levels of three of the four arms of the cross, and pulpit on the fourth arm of the cross. Together these different areas work so that no member of the congregation is more than forty-five feet from the minister, so that movement can take place (through the cloister and stair towers) with minimum interference of the service (late comers entering the seating areas from the back corners) and also so that the exit of the congregation after the service moves "respectfully" toward the pulpit. Moreover the four vertical elements which organize the circulation/seating subsystem are also essential to the other subsystems of Unity Temple. Thus these vertical elements are the structural members which support the roof, a roof which springs from these supports so as to facilitate the existence of skylights which are the major source of (natural) light within the Temple. In

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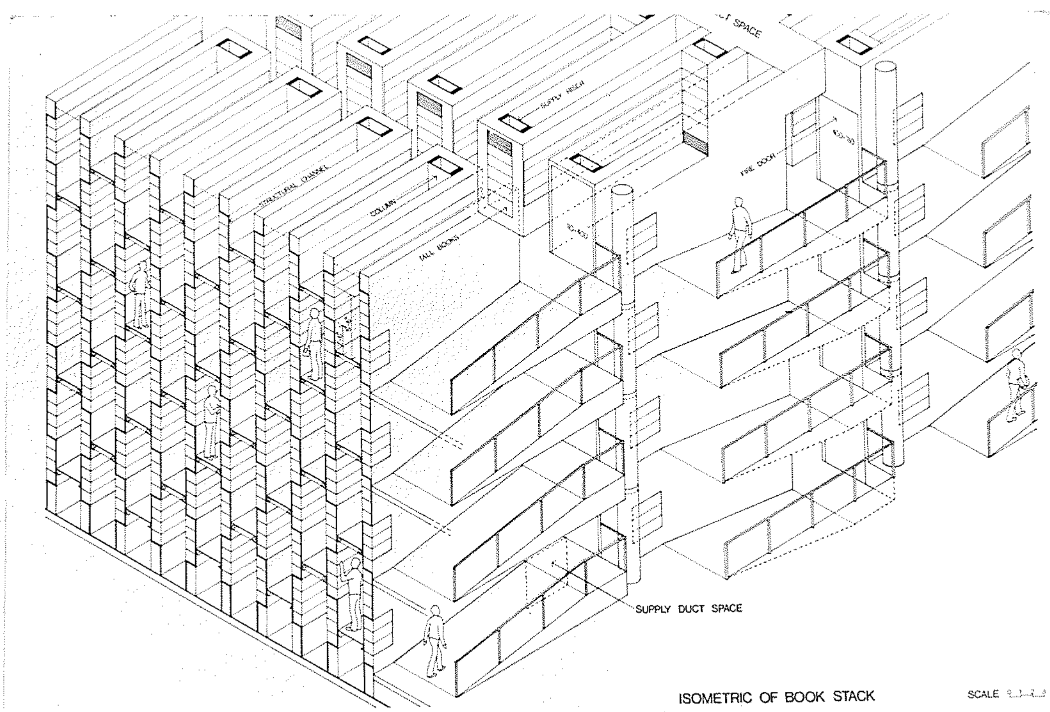
which often accompanies a strong material order. Obviously however a rigorous geometrical order should not be mistaken for a material order. In itself compositional rigorism evolves from a concern for the abstract or perceptual characteristics of the architectural entity not for its material characteristics.

addition these vertical elements are free-standing ducts which distribute heated air throughout the Temple. Thus in these vertical elements, the "keystones" of Unity Temple, the circulation/seating, lighting, structural, and mechanical subsystems all act together.

In 1971 I designed a library bookstack specifically as an investigation into material interdependency. (20) Aside from structural dependence which is necessarily common to all material systems which exist within a gravitational field the elements which make up the stack are interrelated in the following ways: Alternate cross-aisles are slipped vertically so as to define the horizontal supply and exhaust duct spaces. The structural columns and the supply and exhaust risers are the same element. The structural channels which support the floor elements also act as book cases. And the floor element acts not only as a tie which stabilizes the channels but also contains the lighting for the aisle below.

It is evident in these examples that the definitional efficiency characteristic of a highly systemic material nature may lead to materials (in the sense of actual matter) efficiency as well. This is the reason why technologies in which materials efficiency is especially important, such as those of the sea and air, have throughout their history striven to develop entities of increasingly systemic material nature. There is significance in this for all technologies, including building, (as perhaps Buckminster Fuller was first to recognize) for in a future where man finally will be forced to


STRUCTURAL CHANNEL
COLUMN
TALL BOOKS
SUPPLY RISER
FIRE DOOR
SUPPLY DUCT SPACE
ISOMETRIC OF BOOK STACK
SCALE

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manage his materials resources efficiency in this regard may become of paramount importance.[1]

Nonetheless, looking at the buildings just considered the other aspects of systems, variability and changeability, come to mind for each is highly rigid. Indeed, change of any kind, whether it be of state, that is variability, or of system, is seemingly impossible without beginning from "scratch". To all intents and purposes these buildings are invariable and unchangeable. Does this mean that in those respects in which the material nature of a building is highly systemic it is necessarily invariable and unchangeable?

Consider the following buildings which were designed specifically in response to the need for material variability and changeability:

The typical contemporary laboratory and hospital have each attempted to meet the need for variability and changeability within their mechanical services by running these services in special "servant spaces". (21) Within the servant space each mechanical subsystem is deliberately independent of the others so that adjustments or changes in one subsystem are not hindered by the other

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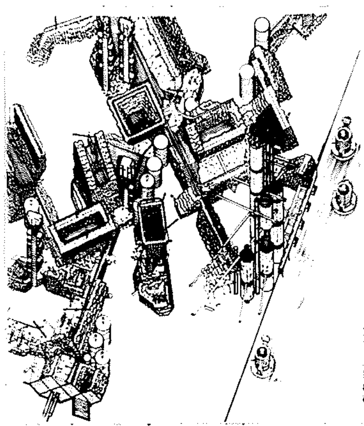
[1] I am not prepared to enter into a discussion as to the relative importance of materials versus energy (labor) efficiency. Suffice it to say that there is no necessary conflict between these two efficiencies.

subsystems.

The "mega-structure" of community services to which various independent "clip-on" or "plug-in" units can be affixed is a similar response to the need for material variability and changeability. (22) Again the essential aspect of this type of scheme is the mutual independence of the various variable and/or changeable parts.

Perhaps the most widely known investigation into material variability and changeability is the School Construction Systems Development (SCSD) sponsored by the Educational Facilities Laboratory in California. (23) The basic intent of SCSD was to develop a series of component parts from which buildings could be assembled in a way that would facilitate material variability and changeability. To this end each component was developed so as to be compatible with, but independent of, the other components. Structure and roof, heating, ventilating and air-conditioning, lighting and ceiling, partitions (fixed, movable, and operable), cabinets, fixed laboratory furniture, and lockers, all were included in the development.

As realized the SCSD project seems to have accomplished its aims. Within the context of the structure each of the other components may be adjusted or changed independently of the others: "Overnight, between two days of a meeting of the board of Educational Facilities Laboratories in the building, a new room was produced by removing 120 feet of interior partition, installing 25 feet, and



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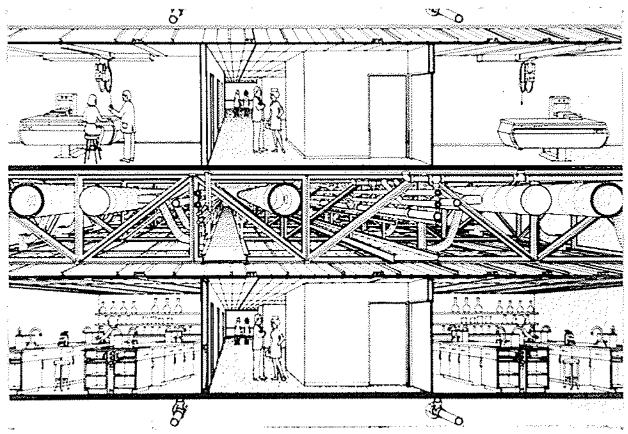

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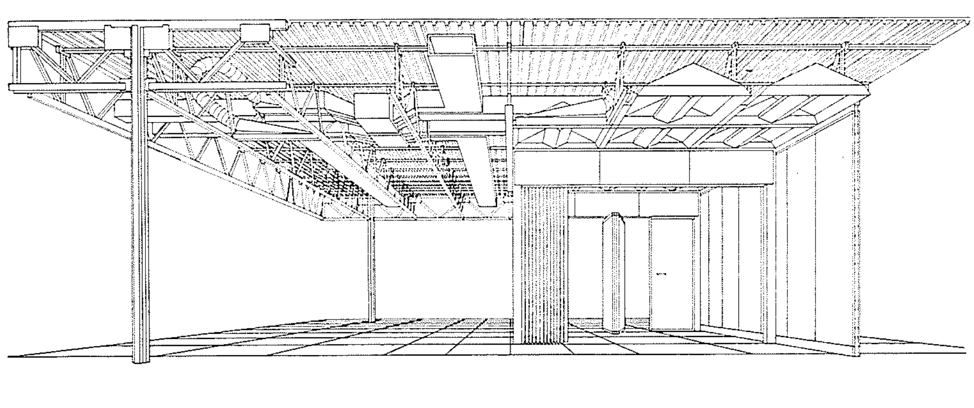

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changing the surface of 80 feet of ceiling panels, seven air-conditioning zones were reduced to five, two thermostats were removed and one changed in position, and the building was tidied up in time for the next morning's meeting. Only 59 man-hours of work were required".[1]

In each of the examples just considered material variability and changeability are facilitated by the independence of parts. Independent of one another one part does not place hindrances upon adjustments or changes isolated within another part. Evidently, in these examples, material variability and changeability are NON-SYSTEMIC characteristics.

This is unfortunate for, theoretically, in addition to the separate advantages which are characteristic of highly systemic, and variable and changeable material natures the dynamic interdependence of parts characteristic of systemic variability and changeability can be most advantageous: As a result of the interdependence of subsystems it is possible to adjust or change an inaccessible subsystem indirectly by adjusting or changing an accessible subsystem. Also as the interdependence of subsystems causes changes in one subsystem to be ramified throughout the others a moderate stimulus appropriately

[1] SCSD: The Project and the Schools, p. 20

administered can result in large scale change throughout the system. Not only that, the change may be self-amplifying and so initiate a process of increasing change.

Perhaps the lack of systemic variability and changeability within the material nature of buildings is the result, quite simply, of an inability on the part of contemporary designers to integrate variability and changeability into a general understanding of the material nature of entities. If this is the case a systemic understanding of variability and changeability awaits a fundamental change in world-view.

However, more likely this lack of systemic variability and changeability within the material nature of buildings is a result of the type of relationship by which the material nature of buildings is defined. The architect's traditional discipline is to order material elements by virtue of their physical definition. The material organization of a building, therefore, is the disposition of elements in physical space. Unfortunately the concrete nature of this type of organization makes it a medium particularly unconducive to systemic variability and changeability.

Interestingly, systemic variability and changeability while uncommon within buildings is exceedingly common among some other types of architectural entities. For example within the shopping district of a city the shops and restaurants are dynamically interdependent: Raising the quality of the restaurants not only draws more people into the restaurant but also draws more people into the shops, similarly, raising the quality of the shops draws more people into both the shops and the restaurants.

Another example is the common redevelopment procedure of initiating a self-amplifying process of improvement within a derelict area by planting a "seed project". As in the previous example the operations of the various members within the group, in this case the buildings within the redevelopment area, are interdependent. The introduction of the seed project, the rejuvenation of one part of the area, raises the potentialities of the other parts of the area. In order to capitalize on their increased potentialities the other buildings within the area are also redeveloped in turn initiating further redevelopment. Thus the process of self-amplifying redevelopment is underway.

System variability and changeability also exist among the material natures of various types of windcraft. A sailboat, for example, is highly systemic, each of the working parts dynamically interdependent upon the others. Yet a sailboat is also highly variable and changeable. It may exist in numerous states through the variation of sails, centerboard, and ballast; the stability of each state dependent upon the interactions of these variable elements. It is also readily changeable in the variety of sails which may be flown; every change having ramifications throughout all of the other working parts.

Systemic variability and changeability is possible within the material natures of architectural entities other than buildings because, unlike buildings which are organized by relations of physical definition, the other architectural entities are organized by OPERATIONAL RELATIONSHIPS. Perhaps where the characteristics of systemic variability and changeability are advantageous the constituent parts of the individual building might also be organized by operational relationships. The operations of these parts must be relatable, of course. Where this is the case it would be to the architect's advantage to enlarge his traditional discipline, with respect to the material order of buildings, to include operational relationships. In any event investigations into the relationships among the operations of the constituent parts of a building would seem to be a most promising field for research.

CHAPTER 8. ARCHITECTURE AS A PHENOMENAL SYSTEM

There is no doubt that a discussion of the material order of the architectural entity is of importance to architects. Nevertheless as the discussion contains no reference to man in his humanity it is necessarily of secondary concern. Obviously, as architecture is the human habitat, the primary concern of the architect is the relation between the architectural entity and man, as man.

The relationships between man, the inhabitant, and the architectural entity constitute the phenomenal order of architecture. That is to say, architecture as a phenomenal system exists in the relationships between the inhabitant and the architectural entity. Architecture in this sense is experience. But experience is not simply sensation. Experience involves perception, the comprehension of sensation. Thus, for example, while the uninitiated may sense, their sensation exists largely without understanding and hence is superficial. This is not to belittle the uninitiated, of course, it is simply to state the generally recognized fact that a certain amount of knowledge is necessary, although not sufficient, for understanding. The sensibility of the inhabitant is most important in experience for, as has already been said, experience exists in the RELATIONSHIPS between the architectural entity and the inhabitant. It is the interaction of two parties, not simply the effect of one, the architectural entity, upon the other, the inhabitant. Experience requires active participation on the part of the inhabitant, an active ordering of what exists in sensation. Experience is a creative act.

Of course, not all sensation can be ordered into a phenomenal whole, AN experience. In order to be an experience the sensations involved must be resolved with respect to one another. The "loose ends" introduced with each sensation must ultimately be tied into the other sensations. Naturally this does not mean that all of the interrelationships which may be experienced must enter into any particular experience. It simply means that experience cannot be partial or fragmentary for the partial and the fragmentary are unresolvable. Experience must be consummated in the active integration of sensation.

As all men are unique experience is unique, unique to the individual and the time; no other individual or even the same individual at another time may be party to exactly the same experience. However, there is a commonality in experience as there is a commonality in man. This is especially so within a particular culture or school of thought in that the individual members share certain relatively highly defined attitudes (toward architecture). Consequently there is much which different individuals experience in common. This commonality is important for it makes a certain amount of generalization about the experience of architecture possible. Without generality the notion that one man, the architect, could design architectural entities suitable to the habitation of other men would be patently ridiculous.

Experience is a creative act unique to the individual. Yet because of the commonalities among men the general nature of experience, in greater or lesser degree, is universal. What then is the general nature of the experience which is architecture, the experience which exists in the relationships between the architectural entity and the inhabitant?

The architectural entity is a definition of limits; a realm which is within the control of the inhabitant or an extension of the inhabitant -- the community or the gods -- even if only on a symbolic level. It is, to quote Le Corbusier, "the first manifestation of man creating his own universe".[1] THE RELATIONSHIP BETWEEN THE ARCHITECTURAL ENTITY AND THE INHABITANT, THEN, IS THE "EXPERIENCE OF DOMAIN", THE INHABITANT'S EXPERIENCE OF THE UNIQUE ATMOSPHERE OF THE ARCHITECTURAL ENTITY WHICH HE INHABITS, THE PHENOMENAL TERRITORY OF THE INDIVIDUAL, THE COMMUNITY, OR THE GODS.[2]

The experience of domain is created by the inhabitant out

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[1] Le Corbusier, Toward a New Architecture, p. 73

[2] The concept of domain is strongly related to the traditional architectural concept of genius loci. There is a distinction between the two, however, in that the concept of domain acknowledges the centrality of man, the inhabitant, as the active integrating agent of experience.

of the myriad of sensations particular to the architectural entity. In this the experience of domain is often multifaceted in nature for the act of inhabiting is often multifaceted in nature. Thus the experience of domain is composed of a multiplicity of "elementary experiences", each of which the inhabitant creates out of the sensations particular to those aspects of the architectural entity which participate in each facet of the act of inhabiting. The experience of domain, therefore, is the larger experience, corresponding to the full range of the acts of inhabiting, into which the inhabitant resolves these "elementary experiences".

The implications of the creative role of the inhabitant in the experience of domain upon the practice of architecture are subtle but profound. Thus the responsibility for the "success" of the experience of domain is not the architect's alone but is shared by the inhabitant. The role of the architect in this respect is not unlike that of a teacher, for rather than do something directly he must make it possible for others to do something. In the experience of domain the architect, using the only means at his disposal, the architectural entity, must prepare the inhabitants, cleansing their minds of extraneous concerns, and then must energize their sensibilities leading them to develop their own insights. Exactly how this is done is impossible to describe in words, of course, for that would be to deny the very existence of those qualities which make the architectural experience uniquely what it is. Needless to say, however, because of the commonality in human experience an architectural entity conceived in terms of a SENSIBLE order in addition to the material, constructional, economic, and building by-law orders which are the result of other considerations, will tend to be more susceptible to the sensibilities of the inhabitant than an architectural entity which is conceived purely in terms of these other orders.

Necessarily, the nature of any sensible order is a function of the mechanics of perception. To architects the most familiar explication of these mechanics is that of Gestalt psychology with respect to visual perception. Indeed the Gestalt understanding of visual order provides the fundamental principles taught in the basic design course given in many schools of architecture. (Obviously there was a general understanding of these principles within the design community before they were formalized by the Gestalt psychologists.) Basically Gestalt psychology has identified various categories -- space, mass, surface, and line -- elements of which are defined by various relations -- proximity, similarity, closure, interpenetration, overlap -- to form visual entities, Gestaltung. This understanding of visual entities is a paradigm example of a systemic understanding of an entity. Needless to say, however, architecture is not solely a "visual art". The architectural entity is experienced with all the senses and hence the sensible order of the architectural entity must be based on an understanding of the mechanics of the full range of human perception. In this respect architects are undoubtedly delinquent. It is evident in the "paper discipline" by which most architectural entities are designed that the architect is in much greater control of the visual order of the architectural entity than the order of any of the other senses. Although this reflects the importance of the visual sense in man's perception of his habitat it most certainly does not reflect the fact that man's other senses may also be critical to the experience of domain. The architectural entity must engage ALL the senses, and the mind through these senses.

The nature of variability and changeability within the experience of domain also has implications upon the practice of architecture. By virtue of the creative role of the inhabitant in the experience of domain the environment of architecture as a phenomenal system consists not only of the physical context of the architectural entity -- the qualities of light and air, land or cityscape, and the activities of the neighborhood -- but also of the cultural context of the inhabitant -- the conceptual frame which determines the structure of his perception. Thus not only is the experience of domain subject to stresses resulting from adjustments and changes within the environs of the architectural entity, it is also subject to stresses resulting from the more or less continuous evolution, regular displacement, and sporadic revolution within the culture of the inhabitant.[1]

However, while the active role of the inhabitant entails an additional range of environmental stresses it also provides an additional means of accommodating all of the stresses which act upon the experience of domain. Thus not only can environmental stresses be obviated by physical adjustments or changes within the architectural entity, they can also be obviated by adjustments or changes in the attitude of the inhabitant towards the architectural entity. An example which dramatizes this possibility would be the change in experience of a religious place which a man has upon conversion to that religion. However, there are many mundane examples such as the

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[1]While contemporary architects feel capable of handling stresses arising from the physical context of the architectural entity they have long considered stresses arising from the cultural context of the inhabitant problematical. Their anxiety in this regard derives from the fact that the architectural entities they wish to build are outside the mainstream of popular culture, the cultural context of their clients. Hence a misfit tends to exist between the client, by virtue of his cultural context, and the architectural entity by virtue of the different cultural context in which it was conceived. This anxiety is only partially justified however. It is justified in that as an element in the experience of domain the architectural entity must be complementary to the inhabitant. In this respect architecture is at most a crystalization of the values of society. However, the architectural entity, as part of the cultural context of the inhabitant, has the legitimate role of helping to form the values of society. Thus insofar as the architectural entity may have the dual nature of being the complement of the inhabitant in the experience of domain while it is also part of his cultural context it may crystalize existing values while it also legitimately works to change existing values.

growing appreciation of "mainstreet" and Las Vegas among the architectural avant-garde following the acceptance of Pop Art. Even stresses resulting from changes within the physical context of the architectural entity may be obviated by a change in the attitude of the inhabitant. For example the urban cathedral was once a place of communal exuberance. Today, however, overshadowed by its burgeoning commercial neighbours this understanding of the cathedral is impossible, now it is a place of refuge, a retreat from community life.

The implication upon the practice of architecture of the subjective nature of variability and changeability is not that the architect need not concern himself with these aspects of the experience of domain -- that the inhabitant can always compensate for a lack of variability and changeability within the architectural entity. Many great domains have been destroyed by changes in their environments. The Villa Savoie was destroyed because its aloof beauty could not tolerate the more earthly presence of the school building which has been constructed upon the same field. So too, Wright's Sturges House has been reduced from an eagle's nest surveying its preserve to an exhibitionistic oddity by the unyielding tide of suburbia. Rather the implication is that in addition to the physical means within the architectural entity the architect can facilitate variability and changeability within the experience of domain by creating entities readily susceptible to multiple understanding.

Aalto's work which is at once part of the Finnish vernacular tradition as well as the heroic age of modern architecture[1] has a consequent multivalence which makes it most susceptible to a wide range of understanding. Many of Aalto's buildings in materials and scale possess a rugged domesticity and economy of means which belies their exuberantly heroic nature. Witness especially the community centre at Saynatsalo. (24) Moreover Aalto's buildings are often enigmatic in their inconsistencies. The dormitory/dining hall which is Baker House, for example. (25)

Perhaps the contemporary architect who most (self) consciously strives to design buildings susceptible to multiple understandings is Robert Venturi. This is much the intention of "complexity and contradiction" in architecture. Describing a house in Chestnut Hill, Pennsylvania (26, 27) which he designed Venturi says,

> "This building recognizes complexities and contradictions: it is both complex and simple, open and closed, big and little: some of its elements are good on one level and bad on another..." [2]

Of course, for Venturi the means by which this is

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[1]Lecture given by Prof. E. Lindgren, University of Manitoba, 1971.

[2]Robert Venturi, Complexity and Contradiction in Architecture, p. 117

accomplished is a matter of a highly refined personal taste.

> "When I called this house both open and closed as well as simple and complex, I was referring to these contradictory characteristics of the outside walls. First, their parapets along with the wall of the upper terrace in back, emphasize horizontal enclosure yet permit an expression of openness behind them at the upper terrace, and above them at the chimney-clerestory protrusion. Second, the consistent shape of the walls in plan emphasizes rigid enclosure, yet the big openings, often precariously close to the corners contradict the expression of enclosure."
>
> "The house is big as well as little, by which I mean that it is a little house with a big scale. Inside the elements are big: the fireplace is "too big" and the mantel "too high" for the size of the room; doors are wide, the chair rail high." "The applied wood moulding over the door increases its scale, too. The dado over the door increases the scale of the building all around because it is higher than you expect it to be. These mouldings affect the scale in another way also: they make the stucco walls even more abstract, and the scale, usually implied by the nature of the materials, more ambiguous or noncommital."
>
> "These complex combinations do not achieve the easy harmony of a few motival parts based on exclusion -- based, that is, on "less is more". Instead they achieve the difficult unity of a medium number of diverse parts based on inclusion and ON ACKNOWLEDGEMENT OF THE DIVERSITY OF EXPERIENCE."[1] (capitals mine)

Architecture exists as the experience of domain in the relationship between the inhabitant and the architectural entity. In this relationship the qualities of the inhabitant are every bit as important as the qualities of the architectural entity. This is important for the architect to remember for while only the architectural

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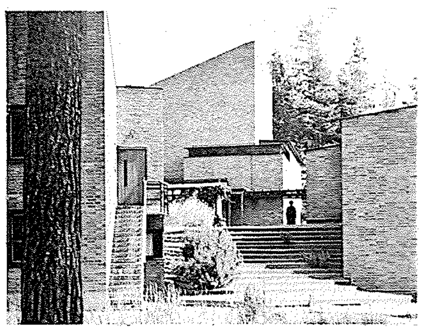
[1] Robert Venturi, Complexity and Contradiction in Architecture, p. 120-121



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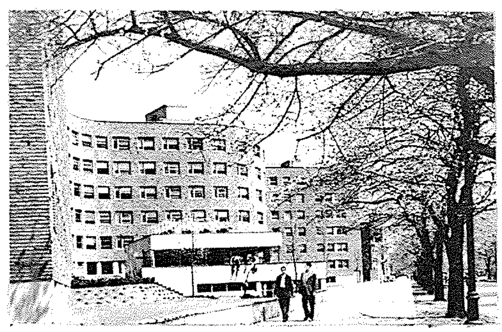

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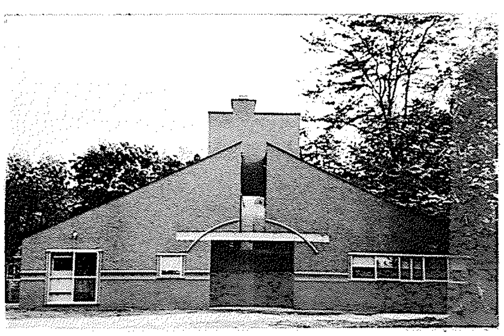

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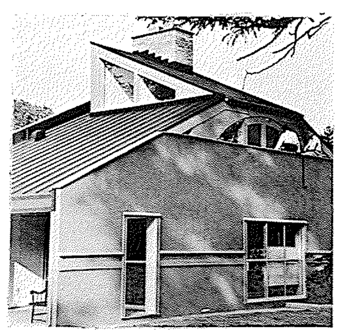

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entity is within his control it is the relationship between the architectural entity and the inhabitant which is his ultimate concern. The creative role of the architect is only fulfilled in the creative role of the inhabitant.

CHAPTER 9. ARCHITECT'S ARCHITECTURE:
The Relation between Architecture as a Material System and Architecture as a Phenomenal System

Considered as a material system architecture exists in the relationships among the material parts of the architectural entity. Considered as a phenomenal system architecture exists in the relationships between the architectural entity and its inhabitants. Each of these considerations of architecture is logically distinct from the other for each is based on logically different kinds of relationships. Nevertheless each consideration has a bearing upon the other. Indeed, in the practice of architecture, the implication of each consideration upon the other is so thoroughgoing that it constitutes the source of one of the central issues of the twentieth century architectural debate.

The interrelation of architecture as a material system and architecture as a phenomenal system begins in the nature of the architectural entity as an element in the experience of domain. This nature, as it is complementary to the sensibilities of the inhabitant, is necessarily a sensible nature. Obviously, however, the sensible nature of the architectural entity is founded in its material existence. That is to say the sensible nature of the architectural entity is determined by those aspects of the material nature of the architectural entity which are manifested in a sensible order. Thus the architect's sole means of control within the experience of domain, the sensible nature of the architectural entity, is a function of his control of certain aspects of the material nature of the architectural entity. Inherently, therefore, the nature of architecture as a material system bears upon the nature of architecture as a phenomenal system.

The implication of the bearing of the material upon the phenomenal is that the architect manipulates the material nature of the architectural entity to achieve the sensible order appropriate to his intentions with respect to the experience of domain. Thus in practice the nature of architecture as a phenomenal system bears upon the nature of architecture as a material system. In this way the practice of architecture involves the resolution of the material nature of the architectural entity with respect to its implications upon the sensible nature of the architectural entity and the resolution of the sensible nature of the architectural entity with respect to its implications upon the material nature of the architectural entity.

Not surprisingly the debate which this interrelation has engendered concerns just how far the architect can legitimately manipulate the material or sensible natures of the architectural entity for the purposes of the other. Although the positions on this question vary considerably there are two general classes into which they can be divided. The first class maintains that as all of the parts of the architectural entity must have material existence they must all have validity within the material order of the architectural entity. The second class maintains that even though all of the parts of the architectural entity must have material existence some of the parts may exist largely or even purely for their validity within the sensible order of the architectural entity.

The extreme position of the first class of arguments is that of "narrow functionalism" or "functional-determinism". Architects of this persuasion maintain that a perfectly resolved material order will necessarily be manifested in a perfectly resolved sensible order. "The ardent functionalist maintains that beauty, or at least a kind of formal perfection results automatically from the most perfect mechanical efficiency; perfectly engineered creations achieve beauty without a conscious search for it on the part of the designer."[1] The validity of this position is doubtful, of course, for it assumes a perfect coincidence of means in two parts of the architectural problem which, while they bear upon one another, are logically distinct.

A somewhat less deterministic formulation of this

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[1]E. R. De Zurko, Origins of Functionalist Theory, frontispiece.

extreme position is based upon the likelihood that there is more than one material order which will satisfy the material needs of the problem. This being the case the material order selected is the one which also is manifested in a sensible order which satisfies the sensible needs of the problem. Needless to say this formulation of the position still does not avoid the criticism that it assumes a coincidence of means which logically need not exist.

Obviously if this class of arguments is to have any validity whatsoever it must take the distinction between the material and sensible nature of the architectural entity into account. Since there is no necessity that the means to the resolution of the material and sensible orders of the architectural entity will coincide, indeed since the means to the resolution of the material and sensible orders of the architectural entity may actually be in conflict, this class of arguments must take the position that it may be necessary to manipulate the material order, even in a detrimental manner, to achieve a satisfactory sensible order. Still, the use of elements within the architectural entity which have little or no validity within the material order; that is, elements whose validity is predominantly within the sensible order, is not accepted within this position. In this sense the argument may be said to make a distinction between architecture and the stage set.

The arguments of the first class are mistaken, however, for they are based on a confusion of priorities. Surely architecture is the HUMAN habitat. Surely in this respect the sensible nature of the architectural entity takes priority over the material nature of the architectural entity , provided that the material order of the architectural entity is at least workable, of course, even if this means encumbering the material order with an aggregation of non-essential elements. Afterall is it not the fundamental difference between architecture and engineering that architecture is a HUMANISTIC discipline?

Based on the priority of man, therefore, the second class of arguments maintains that not only may it be necessary to manipulate the material order of the architectural entity to achieve a satisfactory sensible order it may also be necessary to introduce elements into the architectural entity whose validity is predominantly or even purely within its sensible order. The corner "mullions" of Mies' towers on Lake Shore Drive no less than the pilasters and pediment of Michelangelo's Portia Pia; the exterior canopy of the Centre Le Corbusier no less than the interior canopy of Philip Johnson's guest house; the plaza of Kahn's Salk Institute Buildings no less than the rock and sand garden of a Buddhist monastery; the central columns in the main work space of Wright's Johnson's Wax Building no less than the spinners of Erickson's Canadian Pavilion at Expo 70 in Osaka.

Ideally, both the material and sensible orders of the architectural entity should be resolved without compromise. This would necessitate the elimination of all elements whose validity is predominantly within the sensible order as the material existence of these elements,in that they are materially superfluous and hence materially inefficient, is necessarily detrimental to the material order of the architectural entity. The perfect resolution of both the material and sensible orders of the architectural entity, therefore, is dependent upon the material order being manifested in a fully resolved sensible order. This position is not to be mistaken for that of "functional-determinism", however, for the objective of the functional determinist is solely the resolution of the material order of the architectural entity. Rather it is simply a statement of an ideal which, as such, would satisfy all positions on this question. Necessarily where this perfect resolution of both the material and sensible orders of the architectural entity is not possible the resolution of the sensible order takes precedence over the resolution of the material order, given that the material order is at least workable.

The resolution of both the material and sensible orders of the architectural entity although they may be at odds with one another, is one of the complexities which exists in architectural design. The perfect resolution of both should be one of the goals of the architectural designer. Like all perfection, the achievement of this ideal is impossible, of course. Nevertheless, it is a good standard by which to evaluate the skillfulness in the design of any particular entity. Indeed because this standard concerns the relation of the behind the scenes action and the performance on stage it is the basis for an understanding and appreciation of the architect's art which is uniquely professional. This is an understanding and appreciation of that "architect's architecture" really is.

GLOSSARY

Aggregate	an aggregate is an "entity" constituted of independent parts - one extreme of the continuum of dependency (opposite extreme - whole).
Adaptation	adaptation is the process of change within a system by which its existence is maintained in the face of changing internal and environmental stresses.
Becoming	becoming is the changes within a system by which its existence is maintained in the face of changing internal and environmental stresses; i.e., system morphogenesis.
Behaving	behaving is the acts of a system by which the internal and environmental stresses which act upon it are obviated; i.e., system morphostasis.
Being	being is the pattern of relationships among the elements of a system; i.e., system morphology.
Closed System	a closed system is a system which exchanges neither energy nor information with its environment.
Element	an element is the basic unit which is ordered by the set of relationships which constitute a system. An element is defined by the relationships which order it.
Environment	the environment of a system consists of all those elements which act upon or are acted upon by the system.
Equilibrium	equilibrium is the stability of systems of single state.
Essential Nature	the essential nature of an entity lies in the relationships among its constituent parts; that is, in its organization.

Internal Specialization	a system is internally specialized when its constituent elements are more or less unique in structure and/or function with respect to one another.
Material System	a material system is constituted of the relationships among the material parts of an entity - a machine.
Morphostasis	morphostasis is the stability of systems of multiple state.
Multi-level System	a multi-level system is a system which contains elements which, in themselves, are systems containing elements.
Multi-purpose Element	a multi-purpose element is an element which is shared by different specialized systems.
Open System	an open system is a system which exchanges energy and/or information with its environment.
Overlap	overlap occurs when different systems contain elements in common.
Phenomenal System	a phenomenal system is constituted of the relationships between man and some other entity - an experience.
Revolution	a revolution is a change in the fundamental nature of a system.
Self-amplifying Change	self-amplifying change is a cyclical process in which past changes within a system induce increased further change within the system.
Stability	stability is the condition of a system which behaves so as to maintain its essential nature in the face of internal and environmental stresses.
State	the state of a system at a particular time is the configuration in which its elements exist at that time.

System	a system is an abstraction of an entity on the basis of the organization of its parts. A system is an expression of the essential nature of an entity; an expression of its wholeness.
Variability	variability is the number of potential states in which a system can exist over time.
Whole	a whole is an entity constituted of interdependent parts - one extreme of the continuum of dependency (opposite extreme - aggregate)
Wholeness	the wholeness of an entity is the degree to which its constituent parts are interdependent.

APPENDIX

NOTES ON HOLISM

He who knows does not speak;
He who speaks does not know;
Fill up its apertures,
Close its doors,
Dull its edges,
Untie its tangles,
Soften its light,
Submerge its turmoil,
  This is the Mystic Unity.

Then love and hatred cannot touch him.
Profit and loss cannot reach him.
Honor and disgrace cannot affect him.
Therefore he is always the honored one of the world.[1]

The central point of this Taoist poem is that the real value of words lies in the meaning behind the words which cannot be directly expressed. This meaning is something that everyone must come to understand by himself through his own powers. Understanding is a function of the individual.

Realizing the limitations of language let us proceed to the matter at hand, a discussion of Holism. This paper is essentially a survey whose intention it is to determine the range and power of the concept of holism. To this end Part 1 deals with the men who

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[1] W. Bynner, The Way of Life according to Lao-tzu, Tao #56, pp. 60-61.

formulated theories of holism in abstract terms: the philosophers of holism. Part 2 also deals with men who formulated theories of holism in abstract terms but not as an end in itself, rather as a means to creation: the architects of holism.

THE PHILOSOPHERS OF HOLISM

The philosophers of holism are an extremely diverse group who surprisingly have been very isolated from each other. Indeed the four theories of holism to be discussed in this part of the paper were all formulated without knowledge of the existence of the others.[1] This is all the more surprising when one realizes that three of the four were formulated more or less simultaneously in the second and third decades of this century. The four theories are Smuts' doctrine of Holism and Evolution, Whitehead's theory of Organic Mechanism, the notion of science and complexity, and the ancient Oriental philosophy of Lao-tzu, the Tao.

For the purposes of the paper Smuts' doctrine of Holism and Evolution will be treated much as a warp in weaving for it will be the continuous thread around which the other theories will be weaved.

Smuts begins his considerations by looking at then recent

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[1] J. C. Smuts, Holism and Evolution, Preface to Second Edition.

findings of physical and biological science. On the basis of these findings he suggests the reformation of several fundamental concepts which in turn leads to the establishment of a more general organizing concept.

Reformation of Concepts

In light of the concept of evolution both the concept of matter and the concept of causation as traditionally understood by scientific materialism falls into question. "The acceptance of Evolution as a fact, the origin of life structures from the inorganic, must mean a complete revolution in our idea of matter. If matter holds the promise and potency of life and mind it is no longer the old matter of physical materialism."[1] Consequently the narrow materialist concept of causation, where there is no more in the effect than in the cause, must be denied. Causation makes creativeness and real progress impossible and hence is inconsistent with evolution.

Existence in the space-time of Einstein's relativity also calls for a reconsideration of fundamental concepts for if space and time are interdependent then the view of things as merely spatial is an abstraction, similarly events are temporal only in abstraction --

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[1]Ibid, p. 1

Existence must be in space-time. The implication of this, Smuts concludes, is that the immediate stuff of matter is of only particular significance, pattern or structure, definite organized structure, must be the essential characteristic of the physical universe. In respect to evolution then matter must have a structural energetic constitution which is inherently formative.

Considering the cell and organism Smuts observes that "the system of organic regulation and coordination among an indefinitely large number of parts which makes all the parts function together for certain purposes is a great advance on the system of physical equilibrium in atoms and compounds, and is yet quite distinct from the control which at a later stage of Evolution, Mind comes to exercise in animals and humans." [1] Thus as "we have seen a factor in matter making for structure; we now see a factor in organism making for central coordination and regulation of all parts. We are evidently in the presence of some inner factor in Evolution which requires identification and description."[2]

General Organizing Concept

Evolution is not merely a mechanical unfolding of a

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[1]Ibid, p. 61

[2]Ibid, p. 62

predetermined universe; i.e., the past and the present universe does not contain within it the future universe. Evolution is creative not merely explicative. Creative Evolution involves both general principles and particular structures - both interpenetrating each other, reacting on and vitalizing each other. "Mere structure is not enough, because it misses the generic, the universal in reality. General principles or tendencies are not enough, because they are not concrete such as natural reality is."[1] The fundamental concept of Evolution which takes care of both principle and structure is Holism.

(ASIDE: It is interesting to note here that Lancelot Law Whyte in Accent on Form forwards the notion of form as structure in an attempt to achieve a compromise between what he considers to be the extreme positions of holism and atomism. Clearly, however, Smuts has anticipated this position and has subsumed it as part of holism.)

Holism is the term to designate this whole-ward tendency in Nature, this fundamental factor operative towards the making or creation of wholes in the universe."[2] "The creation of wholes, and ever more highly organized wholes, and of wholeness generally as characteristic of existence, is an inherent character of the universe."[3] "Holism, as the operative factor in the evolution of

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[1]Ibid, p. 94
[2]Ibid, p. 100
[3]Ibid, p. 101

wholes, is the ultimate principle of the universe."[1]

> Since true foundation cannot fail
> But holds as good as new,
> Many a worshipful son should hail
> A father who lived true!
> Realized in one man, fitness has its rise;
> Realized in a family, fitness multiplies;
> Realized in a village, fitness gathers weight;
> Realized in a country, fitness becomes great;
> Realized in the world, fitness fills the skies.
> And thus the fitness of one man,
> You find in the family he began
> You find in the village that accrued,
> You find in the country that ensued,
> You find in the worlds whole multitude.
> How do I know this integrity?
> Because it could all begin in me.[2]

Of the nature of these wholes Smuts is quite clear. "Wholes are composites, and not singles."[3] Thus wholes are made up of parts, however, the relationship between the parts, and between the parts and the whole is not simply mechanical. "It is the very essence of the concept of a whole that the parts are together in a unique specific combination, in a specific internal relatedness, in a creative synthesis which differentiates it from other forms of combination or togetherness. The combination of the elements into this structure is in a sense creative; that is to say, creative of new

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[1]Ibid, p. 101

[2]W. Bynner, The Way of Life according to Tao-tzu, Tao #54, p. 59

[3]J. C. Smuts, Holism and Evolution, p. 104

structure and new properties and functions."[1] In holistic addition, as for example in Gestalt psychology, the whole is greater than the sum of the parts. "The parts in a whole are also affected by the structure of the whole and are different and behave differently from what they would have done apart from such a whole. It is the very essence of a whole that while it is formed of parts it in turn influences the parts and affects their relations and functions. This reciprocal influence constitutes the internality or interior character of a whole."[2] Hence the parts can only be understood in relation to the whole.

> Thirty spokes are made one by holes in a hub,
> By vacancies joining them for a wheel's use;
> The use of clay in moulding pitchers
> Comes from the hollow of its absence;
> Doors, windows, in a house,
> Are used for their emptiness:
> Thus we are helped by what is not
> To use what is.[3]

Holism is not only creative but self-creative for it deepens as you progress along the evolutionary path, thus its final structures are far more holistic than its initial structures. "There is a progressive grading of this holistic synthesis in nature, so

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[1] Ibid, p. 107

[2] Ibid, p. 107

[3] W. Bynner, The Way of Life according to Tao-tzu, Tao #11, p.30

that we pass from a) mere physical mixtures, where the structure is almost negligible, and parts largely preserve their separate characters and activities or functions, to b) chemical compounds, where the structure is more synthetic and the activities and functions are strongly influenced by the new structures and can only with difficulty be traced to the individual parts; and again, to c) organisms, where a still more intense synthesis of elements has been effected, which impresses the parts or organs far more intimately with a unified character, and a system of regulation and coordination, and finally of central control of all parts and organs arises; and from organism, again, on to d) Minds or physical organs, where the Central Control acquires consciousness and freedom and creative power of the most far reaching character; and finally to e) Personality, which is the highest most evolved whole among the structures of the universe, and becomes a new orientative centre of reality."[1]

Parallel Theories

Before considering the implications Smut draws from the doctrine just described, it is interesting to compare it with two other doctrines which arose simultaneously but separately; the first

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[1] J. C. Smuts, Holism and Evolution, p. 88

is Whitehead's Doctrine of Organic Mechanism and the second the general notion of complexity in science. Whereas Smuts comes to his theory on the basis of physical and biological science, Whitehead is guided more particularly by psychological and philosophical analysis.

Whitehead holds that things or objects as traditionally understood are merely abstractions. This is a result largely of the fallacy of "Misplaced Concreteness". That the thing or event taken by itself in its spatial limits is a false simplication which is due to the mistaken belief that a thing or event, as it appears in a definite space at a certain time, is all there is of it, and that it has nothing to do with other spaces or times. However on the basis of Relativity the habitual fundamental assumption that there is a unique meaning to be given to space and a unique meaning to be given to time is denied and hence the particular reality of any thing or event in space-time is dependent upon the particular space-time system chosen. Thus any particular mode; i.e., simple location, in space-time taken in its separateness is an abstraction.

On this basis and with respect to the fact that if there are organic unities in the world then there must be some fundamental organic unity of the whole (world) from which the particular unities can emerge. Whitehead concludes that there must be "one underlying activity of realization, individualizing itself in an interlocked plurality of modes"; that is, there must be a fundamental process in the world which realizes and actualizes individual synthesis or unities which are the real concrete events of the world.

Instead of the abstract entities of scientific materialism Whitehead substitutes the concept of organisms, the patterns which are the concrete realities of the world. His doctrine of organisms he then proceeds to formulate as follows: "The concrete enduring entities are organisms, so that the plan of the whole influences the very characters of the various subordinate organisms which enter into it. In the case of an animal, the mental states enter into the plan of the total organism and thus modify the plans of the successive subordinate organisms until the smallest organisms, such as electrons, are reached. Thus an electron within a living body is different from an electron outside it, by reason of the plan of the body. The electron blindly runs either within or without the body, but it runs within the body in accordance with the general plan of the body, and this plan includes the mental state. But the principal of modification is perfectly general throughout nature, and represents no property peculiar to living bodies. This doctrine involves the abandonment of the traditional scientific materialism, and the substitution of an alternative doctrine of organism. I would term the doctrine the theory of organic mechanism. In this theory, the molecules may blindly occur in accordance with general laws, but the molecules differ in their intrinsic characters according to the general organic plans of the situations in which they find themselves."[1]

"The whole point of the doctrine is the evolution of the complex organisms from antecedent states of less complex organisms. The doctrine thus cries aloud for a conception of organism as fundamental for nature. It also requires an underlying activity - substantial activity - expressing itself in individual embodiments, and evolving in achievements of organisms. The organism is a unit of emergent value, a real fusion of the characters of external objects, emerging for its own sake."[2]

Science and Complexity

Science is a primary source of inspiration for both Smuts and Whitehead. It is therefore not surprising to note that the doctrines, Holism and Organic Mechanism both anticipate and usher in a new conception in science. In the history of science the seventeenth, eighteenth and nineteenth centuries formed a period in which physical science learned to deal with problems of simplicity; that is, problems with usually only two variables. These problems were easily handled within the realm of mechanistic causality. Newton's laws the foundation of modern physics as well as the basic

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[1] A. N. Whitehead, Science and the Modern World, pp. 115-116.
[2] Ibid, p. 157

principles of light, of sound, of heat and of electricity, are all essentially two-variable problems. About the beginning of the twentieth century a new type of problem became the main concern of science - problems of disorganized complexity. These problems are characterized by extreme numbers of variables and hence were impossible to handle through the simple laws of cause and effect. The solution of these problems was the invention of probability theory and of statistical mechanics. Thus problems such as the seemingly random behavior of gas molecules could be easily handled. Indeed, the greater the number of variables the more precise the technique became. It is essential to remember though that in this technique the particular characteristics of the individual is largely irrelevant.

Even though the statistical method of dealing with disorganized complexity was a great advance over the earlier two variable methods of dealing with simplicity a large domain of science was still without any high-powered mathematical techniques. This is the area of the biological sciences where the number of variables is somewhere between two or three variables and astronomical numbers of variables. However, more important than the number of variables in the biological sciences is the characteristic that these variables are all interrelated; that is, they show the essential feature of organization and hence are referred to as problems of organized complexity. Problems of organized complexity are problems of holism.

"A watch spring can be taken out of a watch and its properties usefully studied apart from its normal setting. But if a heart be taken out of a live animal, then there is a great limitation on the range of useful studies which can be made."[1] This is the area presently receiving major consideration in the scientific community (e.g., DNA and life-structures) and I am sure that if Smuts were alive today he would predict that the eventual solution of these problems will involve a formulation so fundamental as to make both problems of simplicity and problems of disorganized complexity merely special cases of problems of organized complexity; that is, holism.

Implications of Smuts' Holism

The most fundamental implication of Smuts' doctrine of holism is the clear distinction that exists between holistic and mechanistic forms of organization. In mechanistic organization the whole or totality is of the same order as the parts. The prime example, indeed ideal or icon, of this type of order is traditional logic and mathematics where 1+1=2; i.e., the parts and the whole are of the same order. However, in holistic organization the parts are not so much added to one another as integrated into one another the

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[1] W. Weaver, 1958 Annual Report of the Rockefeller Foundation, p. 9

resultant being that the totality achieves a new and higher order than the parts. A clear example of this is any living organism. Now obviously both forms of organization exist, therefore the obvious question is how are they related to one another in the natural world. Smuts holds that all natural wholes are both mechanistic and holistic to a degree. Mechanism and holism are opposite poles of a continuum along which all wholes fall - as the whole moves "upward" along the evolutionary path it becomes increasingly holistic. To date the most holistic organisms in existence are the human mind and personality which are not only creative but self-creative.

Another important implication of holism is that the causality of mechanism, the cause and effect of Newtonian physics, is not universal. In holistic organizations the resultant effect is not merely traceable to the cause but has become transformed in the process. This means that the philosophic trap of pre-determination is avoided and freedom and creativity become actual not just empty formalisms. However, Smuts is careful to point out that holism must be seen not only in the changes and variations of progressive evolution but also in the stability of types, for stability is a function of the whole. "It is the fundamental unity or unitariness and wholeness in organisms and organic Evolution generally which seems to explain their essential stability as well as the regulation and coordination of the whole process."[1]

Conclusion

Before creation a presence existed
Self-contained, complete,
Formless, voiceless, mateless,
Changeless,
Which yet prevaded itself
With unending motherhood.
Though there can be no name for it,
I have called it 'the way of life'.
Since fullness implies widening into space,
Implies still further widening,
Implies widening until the circle is whole.
In this sense
The way of life is fulfilled
Heaven is fulfilled,
Earth fulfilled
And a fit man also is fulfilled:
These are the four amplitudes of the universe
And a fit man is one of them:
Man rounding the way of earth,
Earth rounding the way of heaven,
Heaven rounding the way of life
Till the circle is full.[2]

Holism is "the ultimate synthetic, ordering, organizing, regulative activity in the universe which accounts for all the structural groupings and synthesis in it, from the atom and the physio-chemical structures, through the cell, and organisms, through mind in animals, to personality in man. The all pervading and ever

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[1]J. C. Smuts, Holism and Evolution, p. 127

[2]W. Bynner, The Way of Life according to Tao-tzu, Tao #25, p. 40

increasing character of synthetic unity or wholeness in these structures leads to the concept of Holism as the fundamental activity underlying and coordinating all others, and to the view of the universe as a Holistic universe."[1]

THE ARCHITECTS OF HOLISM

Existence is beyond the power of words
To define:
Terms may be used
But are none of them absolute.
In the beginning of heaven and earth there were no words,
Words came out of the womb of matter;
And whether a man dispassionately
Sees to the core of life
Or passionately
Sees the surface,
The core and the surface
Are essentially the same,
Words making them seem different
Only to express appearance.
If name be needed, wonder names them both:
From wonder to wonder
Existence opens.[2]

Frank Lloyd Wright, Buckminster Fuller, and Walter Gropius are really only one architect, or rather they are three different manifestations of one ideal for although in the minds of the architectural community they are three distinct and different men their thought is basically the same, they all hold holism (organic

[1] J. C. Smuts, Holism and Evolution, p. 326.

[2] W. Bynner, The Way of Life according to Tao-tzu, Tao #1, p. 25

architecture, synergy) to be the fundamental operative principle of the universe.

Of course, as Benjamin Lee Whorf has pointed out the language or vocabulary in which a concept is formulated warps that concept so that it can never be perfectly equivalent to a similar concept in another language. Thus in their words but more especially in their works these three architects each present a unique and untranslate-able facet of the general concept of holism.

Walter Gropius

I introduce Gropius as the first of the three "architects of holism", to be considered here for two reasons. The first is that as a theorist Gropius has applied a consistently holistic point of view to a wide range of subjects including the arts, social organization, and education; and by way of his great influence as an educator has been responsible for spreading the gospel of holism to many students. However the second reason that he is considered here first and in an abbreviated form is perhaps an unfair one, the result of my inability to understand the actual manifestations of his thought; that is, his buildings. It seems to me, and I repeat that I am probably being grossly unfair, that Gropius is an architect who knew all the words but could not put them into action. He is there-fore a warning that understanding the words is not enough, this understanding must be made manifest in buildings and this need, it seems to me, indicates where the majority of effort should go, at least until one has achieved mastery, and that is in the translation of thought to action.

Gropius has said, "the idea of bringing back to our deeply disrupted societies the sense for organic relationships and for significant form and meaning of our visual surroundings has governed my life work from its earliest beginnings. All my various endeavours can be understood only when seen as a concerted effort to promote 'unity in diversity' in art, architecture and planning."[1] To exemplify this approach let us consider what Gropius considered the sine qua non for a unified life - the unity of the arts. The vehicle through which Gropius tried to achieve this unity was the Bauhaus. Founded on the basis of "the fundamental unity underlying all branches of design" the Bauhaus was seeking a common denominator in design. "Basic order in design", writes Gropius, "needs first of all a denominator common to all, derived from facts. A common language of visual communication will give the designer a foundation of solidarity for his spontaneous expression in art; it will free him from the sad isolation from which he is suffering at the present since, in a socially disrupted world, we have lost the common key

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[1]Gropius, foreword to The Synthetic Vision of Walter Gropius, by Gilbert Herbert

for understanding in the visual arts."[1] Thus on the establishment of the Bauhaus Gropius calls for the comprehensive building: "Together let us conceive and create the new building of the future, which will embrace architecture and sculpture and painting in one unity, and which will rise one day towards heaven from the hands of a million workers like the crystal symbol of a new faith."[2] Later Gropius writes, "Thus the Bauhaus was inaugurated with the specific object of realizing a modern architectonic art, which, like human nature should be all embracing in scope. Within that sovereign federative union all the different arts (with the various manifestations and tendencies of each) - every branch of design, every form of technique - could be coordinated and find their appointed place. Our ultimate goal, therefore, was the composite but inseparable work of art, the great building."[3]

To illustrate how a largely verbal understanding of the concept of holism is inadequate for the production of architecture let us compare Gropius' Harvard Graduate Centre with the Midway Gardens of which Wright says in his Autobiography, "In the Midway Gardens built in Chicago in 1913 I tried to complete the synthesis;

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[1] Gropius, "Blueprint for an architect's training", p. 72

[2] Gropius, <u>Bauhaus 1919-1928</u>, p. 18

[3] Gropius, <u>The New Architecture and the Bauhaus</u>, p. 43

plantings, furnishings, music, painting and sculpture, all to be one."

Buckminster Fuller

Matthew Arnold's admonition "to see the world whole and keep the vision constant", is perhaps as good a description of Fuller's work as is needed for in all he has done there is a constant relation to what Bucky considers to be the totality or universal quality of a situation. Witness the various terms he constantly uses: "Comprehensive Man", "Comprehensive Design", "total thinking", "World Planning", and "Continuous Man".

Fuller's preoccupations are teleological in nature; that is to use his definition, "the subjective-to-objective intermittent, only-spontaneous, borderline conscious, and within-self communicating system that distills equatable principles - characterizing relative behavior patterns - from out pluralities of matching experiences; reintegrates selections from those net generalized principles in unique experimental control patterns - physically detached from self - as instruments, tools, or other devices admitting to increased technical advantage of man over environmental circumstance, and consciously designed to permit his modification of forward experiences in preferred ways"[1] which translated into English means extracting

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[1]R. B. Fuller, Ideas and Integrities, p. 9

general principles from past experience and then using those principles to invent specific solutions to particular problems.

Of all general principles the most fundamental, and essential for Fuller is the principle of synergy which he defines as "the unique behaviour of whole systems, unpredicted by behaviour of their respective sub-systems' events."[1] The physical model Fuller uses for this principle is the art of sea and air-ocean vessel-building. "Keels and ribs, though inadequate to subsequent stress functions, gain adequate effectiveness only through means of assembly within jigs or cradle, which locally and temporarily position the components until the complementary interactions and shortened modular bracings are completed, whereby the structural behavior pattern of the respective single components is altered into coordinate action of associated vectors, inter-acting to exponentially augmented total advantage."[2] Clearly an expression of holism.

The corollary of the principle of synergy is that of ephemeralization which means, simply, doing more with less. Now if doing more with less is a corollary to holism it is interesting to speculate on the real significance of Mies van der Rohe's famous dictum "Less is More". Surely this can be considered a statement of

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[1]Ibid, p. 21
[2]Ibid, p. 26

holism, deliberately ambiguous though it is. And by way of "less is more" to its opposite "less is a bore" what Venturi calls "either-or" we get to its opposite the clearly holistic "both-and". All of which serves to illustrate how pervasive yet how unknown holism is as a fundamental tenet in architectural theory.

Fuller is the poet-philosopher for the industrial age. For him synergy in its general fundamentality is the essence of the principle of industry. "It is quickly seen that industrialization is not to be considered only as a form of prosaic commercial exploitation but also as a mathematical principle inherent in the universe. This principle, which is most typical of industry, I have identified as the principly of synergy. The functionings of industry are inclusive."[1] This is for Fuller the exact opposite of science whose "essential function is to take the universe apart and measure its parts and sort them into usable categories. The functioning of science is exclusive."[2] Thus the man at the helm in industry is not the scientist it is the designer. "Design puts together combinations of special behaviour elements for the special "process man". It is through design that man evoluted to his present extended manipulation of environment. The functioning of design is comprehensive."[3]

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[1] Ibid, p. 188
[2] Ibid, p. 189
[3] Ibid, p. 189

Like Gropius, Fuller has examined man and his world from the point of view of holism and has decided which man and which institution must lead the way to the new Jerusalem - the designer and industry. Fuller's designer, for which he is the prototype, is a very holistic man. This "total-thinking", "world-planning", "comprehensive designer is an emerging synthesis of artist inventor, mechanic, objective economist, and evolutionary strategist. He bears the same relationship to society in the new interactive continuities of world-wide industrialization that the architect bore to the respective remote independencies of feudal society."[1]

Industry, the comprehensive designers means to saving the world is now called "Continuous-man" and is defined as "the slowly accumulating total world experience and total literate knowledge regarding all the discovered physical resources and generalized patterning principles - in contradistinction to illiterate, discontinuous man, local in time and geography whose nonrelayed experience-won knowledge limited his tool capabilities to devices which any one individual might invent entirely on his own initiative starting nakedly in the wilderness."[2] Continuous-man, holistic industry is nature's second derivative in that like biology, industry,

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[1] Ibid, p. 176
[2] Ibid, p. 282

too, is metabolic and as such falls into the realm of wholes which Smuts would call self-creative. Fuller clearly understands industry to be an evolutionary extension of man.

Frank Lloyd Wright

Whereas Gropius called his architecture "organic", Wright was "Organic Architecture". Wright and his architecture are one, to consider one without the other is impossible.

Fundamentally organic architecture is holistic. "The word Organic denotes in architecture not merely what may hang in a butcher shop, get about on two feet, or be cultivated in a field. The word organic refers to entity; perhaps integral or intrinsic would therefore be a better word to use. As originally used in architecture, organic means part - to - whole - as - whole - to - part. So entity as integral is what is really meant by the word organic. Intrinsic."[1] "A higher order of the spirit has dawned for modern life in this interior concept of lived-space playing with light, taking organic form as the reality of building now an entity by way of native materials and natural methods of structure; forms

[1] F. L. Wright, The Future of Architecture, p. 347.

becoming more naturally significant of ideal and purpose, ultimate in economy and strength. We have, now coming clear an ideal core of which must soon pervade the whole realm of creative man and one that I know now dates back to Lao-tzu 500 B.C., and later, to Jesus himself."[1]

However, for Wright "organic architecture" is more than just "holistic architecture", or rather it is more particular than just holistic architecture. To him organic architecture is characterized by plasticity or continuity, and organic simplicity and, of course, the ideal of nature which is common both to Fuller and to Gropius but which Wright has correctly insisted must not be taken as inherent in the principle of "organic".

"It is the first principle of any growth that the thing grown be no mere aggregation. Integration as entity is first essential - and integration means that no part of anything is of great value in itself except as it be an integrate part of the harmonious whole."[2] This statement of holism provides the clue to Wright's understanding of organic architecture through plasticity or continuity. Plastic was the term Sullivan used to describe his

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[1] Wright, The Natural House, p. 29
[2] Ibid, p. 22

ornament in which the ornament, or object, was integrated with the background, or field, so as to be inseparable and as such he distinguished it from other ornament which was merely applied. Taking this idea Wright generalized it so that the criterion of plastic integration was applied to everything in a building. "If form really followed function it did in a material sense by means of this ideal of plasticity, the spiritual concept of form and function as one - why not throw away the implications of post or upright and beam or horizontal entirely? Have no beams or columns piling up as "joinery". Nor any cornices. Nor any "features" as fixtures. No. Have no appliances of any kind at all, such as pilasters, entablatures, and cornices. Nor put into the building any fixtures whatsoever as "fixtures". Eliminate the separations and separate joints. Classic architecture was all fixation - of - the - fixture. Yes, entirely so. Now why not let walls, ceilings, floors become seen as component parts of each other, their surfaces flowing into each other. To get continuity in the whole, eliminating all constructed features just as Louis Sullivan had eliminated background in his ornament in favor of an integral sense of the whole."[1]

Thus through the concept of continuity, the generalized

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[1] Ibid, p. 39

principle of plasticity, Wright begins to develop an understanding of holism in architecture which was unique to him. "I have since concentrated on plasticity as physical continuity, using it as a practical working principle within the very nature of the building itself in an effort to accomplish this great thing called architecture."[1] "Were the full import of continuity to be grasped aesthetic and structure become completely one."[2] Indeed, everything becomes one thing and one thing becomes everything - the ultimate holistic ideal. (Mies would be the first to agree.)

By way of contrast here it is interesting to consider another architect of holism, Robert Venturi who considers plasticity as the "easy way out" in achieving wholeness. "An architecture of complexity and accommodation does not forsake the whole. In fact, I have referred to a special obligation toward the whole because the whole is difficult to achieve. And I have emphasized the goal of unity rather than of simplification in an art 'whose ... truth (is) in its totality'. The difficult whole in an architecture of complexity and contradiction includes multiplicity and diversity of elements in relationships that are inconsistent or among the weaker kinds perceptually."[3] - doing it the hard way.

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[1] Ibid, p. 40

[2] Ibid, p. 18

[3] Venturi, Contradiction and Complexity in Architecture, p. 89

However, the author of Contradiction and Complexity in Architecture does not disagree with Wright on the question of simplicity which is inherent to Wright's architecture. "The recognition of complexity in architecture does not negate what Louis Kahn has called 'the desire for simplicity'. But aesthetic simplicity which is a satisfaction to the mind derives, when valid and profound, from inner complexity. The Doric temple's simplicity to the eye is achieved through the famous subtleties and precision of its distorted geometry and the contradictions and tensions inherent in its order. The Doric temple could achieve apparent simplicity through real complexity. When complexity disappeared as in the late temples, blandness replaced simplicity."[1] Wright's 'simplicity' is in many cases synonymous with Venturi's 'complexity'. Both agree with Kubler that "a work of art, which is a complex of many stages and levels of crisscrossed intentions, is always intrinsically complicated, however simple its effect may seem"[2] except that Wright demands that its effect be simple always.

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[1] Ibid, p. 25

[2] Kubler, The Shape of Time, p. 11

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