NOTES ON THE SYNTHESIS

OF FORM / *Christopher Alexander*

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TO MY DEAREST JAN

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PREFACE TO THE PAPERBACK EDITION

Today, almost ten years after I wrote this book, one idea stands out clearly for me as the most important in the book: *the idea of the diagrams.*

These diagrams, which, in my more recent work, I have been calling *patterns*, are the key to the process of creating form. In this book I presented the diagrams as the end results of a long process; I put the accent on the process, and gave the diagrams themselves only a few pages of discussion. But once the book was finished, and I began to explore the process which I had described, I found that the diagrams themselves had immense power, and that, in fact, most of the power of what I had written lay in the power of these diagrams.

The idea of a diagram, or pattern, is very simple. It is an abstract pattern of physical relationships which resolves a small system of interacting and conflicting forces, and is independent of all other forces, and of all other possible diagrams. The idea that it is possible to create such abstract relationships one at a time, and to create designs which are whole by fusing these relationships—this amazingly simple idea is, for me, the most important discovery of the book.

I have discovered, since, that these abstract diagrams not only allow you to create a single whole from them, by fusion, but also have other even more important powers. Because the diagrams are independent of one another, you can study them and improve them one at a time, so that their evolution can be gradual and cumulative. More important still, because they are abstract and independent, you can use them to create not just one design, but an infinite variety of designs, all of them free combinations of the same set of patterns.

As you can see, it is the independence of the diagrams which gives them these powers. At the time I wrote this book, I was very much concerned with the formal definition of "independence," and the idea of using a mathematical method to discover systems of forces and diagrams which are independent. *But once the book was written, I discovered that it is quite unnecessary to use such a complicated and formal way of getting at the independent diagrams.*

If you understand the need to create independent diagrams, which resolve, or solve, systems of interacting human forces, you will find that you can create, and develop, these diagrams piecemeal, one at a time, in the most natural way, out of your experience of buildings and design, simply by thinking about the forces which occur there and the conflicts between these forces.

I have written about this realization and its consequences, in other, more recent works. But I feel it is important to say it also here, to make you alive to it before you read the book, since so many readers have focused on the *method which leads to* the creation of the diagrams, not on the *diagrams themselves*, and have even made a cult of following this method.

Indeed, since the book was published, a whole academic field has grown up around the idea of "design methods"—and I have been hailed as one of the leading exponents of these so-called design methods. I am very sorry that this has happened, and want to state, publicly, that I reject the whole idea of design methods as a subject of study, since I think it is absurd to separate the study of designing from the practice of design. In fact, people who study design methods without also practicing design are almost always frustrated designers who have no sap in them, who have lost, or never had, the urge to shape things. Such a person will never be able to say anything sensible about "how" to shape things either.

Poincaré once said: "Sociologists discuss sociological methods; physicists discuss physics." I love this statement. Study of method by itself is always barren, and people who have treated this book as if it were a book about "design method" have almost always missed the point of the diagrams, and their great importance, because they have been obsessed with the details of the method I propose for getting at the diagrams.

No one will become a better designer by blindly following this method, or indeed by following any method blindly. On the other hand, if you try to understand the idea that you can create abstract patterns by studying the implication of limited systems of forces, and can create new forms by free combination of these patterns—and realize that this will only work if the patterns which you define deal with systems of forces whose internal interaction is very dense, and whose interaction with the other forces in the world is very weak—then, in the process of trying to create such diagrams or patterns for yourself, you will reach the central idea which this book is all about.

C.A.

Berkeley, California
February 1971

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"First, the taking in of scattered particulars under one Idea, so that everyone understands what is being talked about . . . Second, the separation of the Idea into parts, by dividing it at the joints, as nature directs, not breaking any limb in half as a bad carver might."

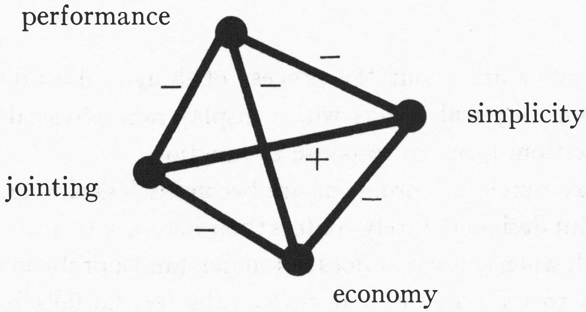
Plato, *Phaedrus*, 265D

1 / INTRODUCTION: THE NEED FOR RATIONALITY

These notes are about the process of design; the process of inventing physical things which display new physical order, organization, form, in response to function.

Today functional problems are becoming less simple all the time. But designers rarely confess their inability to solve them. Instead, when a designer does not understand a problem clearly enough to find the order it really calls for, he falls back on some arbitrarily chosen formal order. The problem, because of its complexity, remains unsolved.

Consider a simple example of a design problem, the choice of the materials to be used in the mass production of any simple household object like a vacuum cleaner. Time and motion studies show that the fewer different kinds of materials there are, the more efficient factory assembly is — and therefore demand a certain simplicity in the variety of materials used. This need for simplicity conflicts with the fact that the form will function better if we choose the best material for each separate purpose separately. But then, on the other hand, functional diversity of materials makes for expensive and complicated joints between components, which is liable to make maintenance less easy. Further still, all three issues, simplicity, performance, and jointing, are at odds with our desire to minimize the cost of the materials. For if we choose the cheapest material for each separate task, we shall not necessarily have simplicity, nor optimum performance, nor materials which can be cleanly jointed. Writing a minus sign beside a line for conflict, and a plus beside a line for positive agreement, we see that even this simple problem has the five-way conflict pictured below.



This is a typical design problem; it has requirements which have to be met; and there are interactions between the requirements, which makes the requirements hard to meet. This problem is simple to solve. It falls easily within the compass of a single man's intuition. But what about a more complicated problem?

Consider the task of designing a complete environment for a million people. The ecological balance of human and animal and plant life must be correctly adjusted both internally and to the given exterior physical conditions. People must be able to lead the individual lives they wish for. The social conditions induced must not lead to gross ill-health or to gross personal misery, and must not cause criminal delinquency. The cyclical intake of food and goods must not interfere with the regular movements of the inhabitants. The economic forces which develop must not lead to real-estate speculation which destroys the functional relation between residential areas and areas supporting heavy goods. The transportation system must not be organized so that it creates a demand that aggravates its own congestion. People must somehow be able to live in close cooperation and yet pursue the most enormous variety of interests. The physical layout must be compatible with foreseeable future regional developments. The conflict between population growth and diminishing water resources, energy resources, parklands, must somehow be taken care of. The environment must be organized so that its own regeneration and reconstruction does not constantly disrupt its performance.

As in the simpler example, each of these issues interacts with several of the others. But in this case each issue is itself a vast problem; and the pattern of interactions is vastly complicated. The difference between these two cases is really like the difference between the problem of adding two and two, and the problem of calculating the seventh root of a fifty digit number. In the first case we can quite easily do it in our heads. In the second case, the complexity of the problem will defeat us unless we find a simple way of writing it down, which lets us break it into smaller problems.

Today more and more design problems are reaching insoluble levels of complexity. This is true not only of moon bases, factories, and radio receivers, whose complexity is internal, but even of villages and teakettles. In spite of their superficial simplicity, even these problems have a background of needs and activities which is becoming too complex to grasp intuitively.

To match the growing complexity of problems, there is a growing body of information and specialist experience. This information is hard to handle; it is widespread, diffuse, unorganized.[1] Moreover, not only is the quantity of information itself by now beyond the reach of single designers, but the various specialists who retail it are narrow and unfamiliar with the form-makers' peculiar problems, so that it is never clear quite how the designer should best consult them.[2] As a result, although ideally a form should reflect all the known facts relevant to its design, in fact the average designer scans whatever information he happens on, consults a consultant now and then when faced by extra-special difficulties, and introduces this randomly selected information into forms otherwise dreamt up in the artist's studio of his mind. The technical difficulties of grasping all the information needed for the construction of such a form are out of hand — and well beyond the fingers of a single individual.[3]

At the same time that the problems increase in quantity, complexity, and difficulty, they also change faster than before. New materials are developed all the time, social patterns alter quickly, the culture itself is changing faster than it has ever changed before. In the past — even after the intellectual upheaval of the Renaissance — the individual designer would stand to *some* extent upon the shoulders of his predecessors. And although he was expected to make more and more of his own decisions as traditions gradually dissolved, there was always still some body of tradition which made his decisions easier. Now the last shreds of tradition are being torn from him. Since cultural pressures change so fast, any slow development of form becomes impossible. Bewildered, the form-maker stands alone. He has to make clearly conceived forms without the possibility of trial and error over time. He has to be encouraged now to think his task through from the beginning, and to "create" the form he is concerned with, for what once took many generations of gradual development is now attempted by a single individual.[4] But the burden of a thousand years falls heavily on one man's shoulders, and this burden has not yet materially been lightened. The intuitive resolution of contemporary design problems simply lies beyond a single individual's integrative grasp.

Of course there are no definite limits to this grasp (especially in view of the rare cases where an exceptional talent breaks all bounds). But if we look at the lack of organization and lack of clarity of the forms around us, it is plain that their design has often taxed their designer's cognitive capacity well beyond the limit. The idea that the capacity of man's invention is limited is not so surprising, after all. In other areas it has been shown, and we admit readily enough, that there are bounds to man's cognitive and creative capacity. There are limits to the difficulty of a laboratory problem which he can solve;[5] to the number of issues he can consider simultaneously;[6] to the complexity of a decision he can handle wisely.[7] There are no absolute limits in any of these cases (or usually even any scale on which such limits could be specified); yet in practice it is clear that there are limits of some sort. Similarly, the very frequent failure of individual designers to produce well organized forms suggests strongly that there are limits to the individual designer's capacity.

We know that there are similar limits to an individual's capacity for mental arithmetic. To solve a sticky arithmetical problem, we need a way of setting out the problem which makes it perspicuous. Ordinary arithmetic convention gives us such a way. Two minutes with a pencil on the back of an envelope lets us solve problems which we could not do in our heads if we tried for a hundred years. But at present we have no corresponding way of simplifying design problems for ourselves. These notes describe a way of representing design problems which does make them easier to solve. It is a way of reducing the gap between the designer's small capacity and the great size of his task.

Part One contains a general account of the nature of design problems. It describes the way such problems have been solved in the past: first, in cultures where new problems are so rare that there are no actual designers; and then, by contrast, in cultures where new problems occur all the time, so that they have to be solved consciously by designers. From the contrast between the two, we shall learn how to represent a design problem so that it can be solved. Part Two describes the representation itself, and the kind of analysis the representation allows. Appendix 1 shows by example how the method works in practice.

The analysis of design problems is by no means obviously possible. There is a good deal of superstition among designers as to the deathly effect of analysis on their intuitions — with the unfortunate result that very few designers have tried to understand the process of design analytically. So that we get off to a fair start, let us try first to lay the ghosts which beset designers and make them believe that analysis is somehow at odds with the real problem of design.

It is not hard to see why the introduction of mathematics into design is likely to make designers nervous. Mathematics, in the popular view, deals with magnitude. Designers recognize, correctly, that calculations of magnitude only have strictly limited usefulness in the invention of form, and are therefore naturally rather skeptical about the possibility of basing design on mathematical methods.[8] What they do not realize, however, is that modern mathematics deals at least as much with questions of order and relation as with questions of magnitude. And though even this kind of mathematics may be a poor tool if used to prescribe the physical nature of forms, it can become a very powerful tool indeed if it is used to explore the conceptual order and pattern which a problem presents to its designer.

Logic, like mathematics, is regarded by many designers with suspicion. Much of it is based on various superstitions about the kind of force logic has in telling us what to do. First of all, the word "logic" has some currency among designers as a reference to a particularly unpleasing and functionally unprofitable kind of formalism.[9] The so-called logic of Jacques François Blondel or Vignola, for instance, referred to rules according to which the elements of architectural style could be combined.[10] As rules they may be logical. But this gives them no special force unless there is also a legitimate relation between the system of logic and the needs and forces we accept in the real world. Again, the cold visual "logic" of the steel-skeleton office building seems horribly constrained, and if we take it seriously as an intimation of what logic is likely to do, it is certain to frighten us away from analytical methods.[11] But no one shape can any more be a consequence of the use of logic than any other, and it is nonsense to blame rigid physical form on the rigidity of logic. It is not possible to set up premises, trace through a series of deductions, and arrive at a form which is logically determined by the premises, unless the premises already have the seeds of a particular plastic emphasis built into them. There is no legitimate sense in which deductive logic can prescribe physical form for us.

But, in speaking of logic, we do not need to be concerned with processes of inference at all. While it is true that a great deal of what is generally understood to be logic is concerned with deduction, logic, in the widest sense, refers to something far more general. It is concerned with the form of abstract structures, and is involved the moment we make pictures of reality and then seek to manipulate these pictures so that we may look further into the reality itself. It is the business of logic to invent purely artificial structures of elements and relations. Sometimes one of these structures is close enough to a real situation to be allowed to represent it. And then, because the logic is so tightly drawn, we gain insight into the reality which was previously withheld from us.[12]

The use of logical structures to represent design problems has an important consequence. It brings with it the loss of innocence. A logical picture is easier to criticize than a vague picture since the assumptions it is based on are brought out into the open. Its increased precision gives us the chance to sharpen our conception of what the design process involves. But once what we do intuitively can be described and compared with nonintuitive ways of doing the same things, we cannot go on accepting the intuitive method innocently. Whether we decide to stand for or against pure intuition as a method, we must do so for reasons which can be discussed.

I wish to state my belief in this loss of innocence very clearly, because there are many designers who are apparently not willing to accept the loss. They insist that design must be a purely intuitive process: that it is hopeless to try and understand it sensibly because its problems are too deep.

There has already been one loss of innocence in the recent history of design; the discovery of machine tools to replace hand craftsmen. A century ago William Morris, the first man to see that the machines were being misused, also retreated from the loss of innocence. Instead of accepting the machine and trying to understand its implications for design, he went back to making exquisite handmade goods.[13] It was not until Gropius started his Bauhaus that designers came to terms with the machine and the loss of innocence which it entailed.[14]

Now we are at a second watershed. This time the loss of innocence is intellectual rather than mechanical. But again there are people who are trying to pretend that it has not taken place. Enormous resistance to the idea of systematic processes of design is coming from people who recognize correctly the importance of intuition, but then make a fetish of it which excludes the possibility of asking reasonable questions.

It is perhaps worth remembering that the loss of intellectual innocence was put off once before. In the eighteenth century already, certain men, Carlo Lodoli and Francesco Algarotti in Italy and the Abbé Laugier in France, no longer content to accept the formalism of the academies, began to have serious doubts about what they were doing, and raised questions of just the sort that have led, a hundred and fifty years later, to the modern revolutionary ideas on form.[15] Oddly enough, however, though these serious doubts were clearly expressed and widely read, architecture did not develop from them in the direction indicated. The doubts and questions were forgotten. Instead, in late eighteenth century Europe, we find evidence of quite another atmosphere developing, in which architects based their formal invention on the rules provided by a variety of manners and "styles" like neo-Tudor, neoclassicism, chinoiserie, and neo-Gothic.[16]

It is possible to see in this course of events a desperate attempt to ward off the insecurity of selfconsciousness, and to maintain the security of innocence.

Lodoli and Laugier wanted to know what they were doing as makers of form. But the search for this knowledge only made the difficulty of their questions clear. Rather than face the responsibility of these difficult questions, designers turned instead to the authority of resurrected "styles." The architectural decisions made within a style are safe from the nagging difficulty of doubt, for the same reason that decisions are easier to make under tradition and taboo than on one's own responsibility. It is no coincidence, in my opinion, that while the Renaissance had allowed free recombinations of classical elements, the neoclassicism which replaced it stuck as closely as it could to the precise detail of Greece and Rome. By leaning on correctness, it was possible to alleviate the burden of decision. To make the secession from responsibility effective, the copy had to be exact.[17]

Now it looks as though a second secession from responsibility is taking place. It is not possible today to escape the responsibility of considered action by working within academic styles. But the designer who is unequal to his task, and unwilling to face the difficulty, preserves his innocence in other ways. The modern designer relies more and more on his position as an "artist," on catchwords, personal idiom, and intuition — for all these relieve him of some of the burden of decision, and make his cognitive problems manageable. Driven on his own resources, unable to cope with the complicated information he is supposed to organize, he hides his incompetence in a frenzy of artistic individuality. As his capacity to invent clearly conceived, well-fitting forms is exhausted further, the emphasis on intuition and individuality only grows wilder.[18]

In this atmosphere the designer's greatest gift, his intuitive ability to organize physical form, is being reduced to nothing by the size of the tasks in front of him, and mocked by the efforts of the "artists." What is worse, in an era that badly needs designers with a synthetic grasp of the organization of the physical world, the real work has to be done by less gifted engineers, because the designers hide their gift in irresponsible pretension to genius.

We must face the fact that we are on the brink of times when man may be able to magnify his intellectual and inventive capability, just as in the nineteenth century he used machines to magnify his physical capacity.[19] Again, as then, our innocence is lost. And again, of course, the innocence, once lost, cannot be regained. The loss demands attention, not denial.

PART ONE

2 / GOODNESS OF FIT

The ultimate object of design is form.

The reason that iron filings placed in a magnetic field exhibit a pattern — or have form, as we say — is that the field they are in is not homogeneous. If the world were totally regular and homogeneous, there would be no forces, and no forms. Everything would be amorphous. But an irregular world tries to compensate for its own irregularities by fitting itself to them, and thereby takes on form.[1] D'Arcy Thompson has even called form the "diagram of forces" for the irregularities.[2] More usually we speak of these irregularities as the functional origins of the form.

The following argument is based on the assumption that physical clarity cannot be achieved in a form until there is first some programmatic clarity in the designer's mind and actions; and that for this to be possible, in turn, the designer must first trace his design problem to its earliest functional origins and be able to find some sort of pattern in them.[3] I shall try to outline a general way of stating design problems which draws attention to these functional origins, and makes their pattern reasonably easy to see.

It is based on the idea that every design problem begins with an effort to achieve fitness between two entities: the form in question and its context.[4] The form is the solution to the problem; the context defines the problem. In other words, when we speak of design, the real object of discussion is not the form alone, but the ensemble comprising the form and its context. Good fit is a desired property of this ensemble which relates to some particular division of the ensemble into form and context.[5]

There is a wide variety of ensembles which we can talk about like this. The biological ensemble made up of a natural organism and its physical environment is the most familiar: in this case we are used to describing the fit between the two as well-adaptedness.[6] But the same kind of objective aptness is to be found in many other situations. The ensemble consisting of a suit and tie is a familiar case in point; one tie goes well with a certain suit, another goes less well.[7] Again, the ensemble may be a game of chess, where at a certain stage of the game some moves are more appropriate than others because they fit the context of the previous moves more aptly.[8] The ensemble may be a musical composition — musical phrases have to fit their contexts too: think of the perfect rightness when Mozart puts just *this* phrase at a certain point in a sonata.[9] If the ensemble is a truckdriver plus a traffic sign, the graphic design of the sign must fit the demands made on it by the driver's eye. An object like a kettle has to fit the context of its use, and the technical context of its production cycle.[10] In the pursuit of urbanism, the ensemble which confronts us is the city and its habits. Here the human background which defines the need for new buildings, and the physical environment provided by the available sites, make a context for the form of the city's growth. In an extreme case of this kind, we may even speak of a culture itself as an ensemble in which the various fashions and artifacts which develop are slowly fitted to the rest.[11]

The rightness of the form depends, in each one of these cases, on the degree to which it fits the rest of the ensemble.[12]

We must also recognize that no one division of the ensemble into form and context is unique. Fitness across any one such division is just one instance of the ensemble's internal coherence. Many other divisions of the ensemble will be equally significant. Indeed, in the great majority of actual cases, it is necessary for the designer to consider several different divisions of an ensemble, superimposed, at the same time.

Let us consider an ensemble consisting of the kettle plus everything about the world outside the kettle which is relevant to the use and manufacture of household utensils. Here again there seems to be a clear boundary between the teakettle and the rest of the ensemble, if we want one, because the kettle itself is a clearly defined kind of object. But I can easily make changes in the boundary. If I say that the kettle is the wrong way to heat domestic drinking water anyway, I can quickly be involved in the redesign of the entire house, and thereby push the context back to those things outside the house which influence the house's form. Alternatively I may claim that it is not the kettle which needs to be redesigned, but the method of heating kettles. In this case the kettle becomes part of the context, while the stove perhaps is form.

There are two sides to this tendency designers have to change the definition of the problem. On the one hand, the impractical idealism of designers who want to redesign entire cities and whole processes of manufacture when they are asked to design simple objects is often only an attempt to loosen difficult constraints by stretching the form-context boundary.

On the other hand, this way in which the good designer keeps an eye on the possible changes at every point of the ensemble is part of his job. He is bound, if he knows what he is doing, to be sensitive to the fit at several boundaries within the ensemble at once. Indeed, this ability to deal with several layers of form-context boundaries in concert is an important part of what we often refer to as the designer's sense of organization. The internal coherence of an ensemble depends on a whole net of such adaptations. In a perfectly coherent ensemble we should expect the two halves of every possible division of the ensemble to fit one another.

It is true, then, that since we are ultimately interested in the ensemble as a whole, there is no good reason to divide it up just once. We ought always really to design with a number of nested, overlapped form-context boundaries in mind. Indeed, the form itself relies on its own inner organization and on the internal fitness between the pieces it is made of to control its fit as a whole to the context outside.

However, since we cannot hope to understand this highly interlaced and complex phenomenon until we understand how to achieve fit at a single arbitrarily chosen boundary, we must agree for the present to deal only with the simplest problem. Let us decide that, for the duration of any one discussion, we shall maintain the same single division of a given ensemble into form and context, even though we acknowledge that the division is probably chosen arbitrarily. And let us remember, as a corollary, that for the present we shall be giving no deep thought to the internal organization of the form as such, but only to the simplest premise and aspect of that organization: namely, that fitness which is the residue of adaptation across the single form-context boundary we choose to examine.[13]

The form is a part of the world over which we have control, and which we decide to shape while leaving the rest of the world as it is. The context is that part of the world which puts demands on this form; anything in the world that makes demands of the form is context. Fitness is a relation of mutual acceptability between these two. In a problem of design we want to satisfy the mutual demands which the two make on one another. We want to put the context and the form into effortless contact or frictionless coexistence.

We now come to the task of characterizing the fit between form and context. Let us consider a simple specific case.

It is common practice in engineering, if we wish to make a metal face perfectly smooth and level, to fit it against the surface of a standard steel block, which is level within finer limits than those we are aiming at, by inking the surface of this standard block and rubbing our metal face against the inked surface. If our metal face is not quite level, ink marks appear on it at those points which are higher than the rest. We grind away these high spots, and try to fit it against the block again. The face is level when it fits the block perfectly, so that there are no high spots which stand out any more.

This ensemble of two metal faces is so simple that we shall not be distracted by the possibility of multiple form-context boundaries within it. There is only one such boundary worth discussion at a macroscopic level, that between the standard face (the context), and the face which we are trying to smooth (the form.) Moreover, since the context is fixed, and only the form variable, the task of smoothing a metal face serves well as a paradigm design problem. In this case we may distinguish good fit from bad experimentally, by inking the standard block, putting the metal face against it, and checking the marking that gets transferred. If we wish to judge the form without actually putting it in contact with its context, in this case we may also do so. If we define levelness in mathematical terms, as a limitation on the variance which is permitted over the surface, we can test the form itself, without testing it against the context. We can do this because the criterion for levelness is, simultaneously, a description of the required form, and also a description of the context.

Consider a second, slightly more complex example. Suppose we are to invent an arrangement of iron filings which is stable when placed in a certain position in a given magnetic field. Clearly we may treat this as a design problem. The iron filings constitute a form, the magnetic field a context. Again we may easily judge the fit of a form by placing it in the magnetic field, and watching to see whether any of the filings move under its influence. If they do not, the form fits well. And again, if we wish to judge the fit of the form without recourse to this experiment, we may describe the lines of force of the magnetic field in mathematical terms, and calculate the fit or lack of fit. As before, the opportunity to evaluate the form when it is away from its context depends on the fact that we can give a precise mathematical description of the context (in this case the equations of the magnetic field).

In general, unfortunately, we cannot give an adequate description of the context we are dealing with. The fields of the contexts we encounter in the real world cannot be described in the unitary fashion we have found for levelness and magnetic fields. There is as yet no theory of ensembles capable of expressing a unitary description of the varied phenomena we encounter in the urban context of a dwelling, for example, or in a sonata, or a production cycle.

Yet we certainly need a way of evaluating the fit of a form which does not rely on the experiment of actually trying the form out in the real world context. Trial-and-error design is an admirable method. But it is just real world trial and error which we are trying to replace by a symbolic method, because real trial and error is too expensive and too slow.

The experiment of putting a prototype form in the context itself is the real criterion of fit. A complete unitary description of the demands made by the context is the only fully adequate nonexperimental criterion. The first is too expensive, the second is impossible: so what shall we do?

Let us observe, first of all, that we should not really expect to be able to give a unitary description of the context for complex cases: if we could do so, there would be no problems of design. The context and the form are complementary. This is what lies behind D'Arcy Thompson's remark that the form is a diagram of forces.[14] Once we have the diagram of forces in the literal sense (that is, the field description of the context), this will in essence also describe the form as a complementary diagram of forces. Once we have described the levelness of the metal block, or the lines of force of the magnetic field, there is no conceptual difficulty, only a technical one, in getting the form to fit them, because the unitary description of the context is in both cases also a description of the required form.

In such cases there is no design problem. *What does make design a problem in real world cases is that we are trying to make a diagram for forces whose field we do not understand.*[15] Understanding the field of the context and inventing a form to fit it are really two aspects of the same process. It is because the context is obscure that we cannot give a direct, fully coherent criterion for the fit we are trying to achieve; and it is also its obscurity which makes the task of shaping a well-fitting form at all problematic. What do we do about this difficulty in everyday cases? Good fit means something, after all — even in cases where we cannot give a completely satisfactory fieldlike criterion for it. How is it, cognitively, that we experience the sensation of fit?

If we go back to the procedure of leveling metal faces against a standard block, and think about the way in which good fit and bad fit present themselves to us, we find a rather curious feature. Oddly enough, the procedure suggests no direct practical way of identifying good fit. We recognize bad fit whenever we see a high spot marked by ink. But in practice we see good fit only from a negative point of view, as the limiting case where there are no high spots.

Our own lives, where the distinction between good and bad fit is a normal part of everyday social behavior, show the same feature. If a man wears eighteenth-century dress today, or wears his hair down to his shoulders, or builds Gothic mansions, we very likely call his behavior odd; it does not fit our time. These are abnormalities. Yet it is such departures from the norm which stand out in our minds, rather than the norm itself. Their wrongness is somehow more immediate than the rightness of less peculiar behavior, and therefore more compelling. Thus even in everyday life the concept of good fit, though positive in meaning, seems very largely to feed on negative instances; it is the aspects of our lives which are obsolete, incongruous, or out of tune that catch our attention.

The same happens in house design. We should find it almost impossible to characterize a house which fits its context. Yet it is the easiest thing in the world to name the specific kinds of misfit which prevent good fit. A kitchen which is hard to clean, no place to park my car, the child playing where it can be run down by someone else's car, rainwater coming in, overcrowding and lack of privacy, the eye-level grill which spits hot fat right into my eye, the gold plastic doorknob which deceives my expectations, and the front door I cannot find, are all misfits between the house and the lives and habits it is meant to fit. These misfits are the forces which must shape it, and there is no mistaking them. Because they are expressed in negative form they are specific, and tangible enough to talk about.

The same thing happens in perception. Suppose we are given a button to match, from among a box of assorted buttons. How do we proceed? We examine the buttons in the box, one at a time; but we do not look directly for a button which fits the first. What we do, actually, is to scan the buttons, rejecting each one in which we notice some discrepancy (this one is larger, this one darker, this one has too many holes, and so on), until we come to one where we can see no differences. Then we say that we have found a matching one. Notice that here again it is much easier to explain the misfit of a wrong button than to justify the congruity of one which fits.

When we speak of bad fit we refer to a single identifiable property of an ensemble, which is immediate in experience, and describable. Wherever an instance of misfit occurs in an ensemble, we are able to point specifically at what fails and to describe it. It seems as though in practice the concept of good fit, describing only the absence of such failures and hence leaving us nothing concrete to refer to in explanation, can only be explained indirectly; it is, in practice, as it were, the disjunction of all possible misfits.[16]

With this in mind, I should like to recommend that we should always expect to see the process of achieving good fit between two entities as a negative process of neutralizing the incongruities, or irritants, or forces, which cause misfit.[17]

It will be objected that to call good fit the absence of certain negative qualities is no more illuminating than to say that it is the presence of certain positive qualities.[18] However, though the two are equivalent from a logical point of view, from a phenomenological and practical point of view they are very different.[19] In practice, it will never be as natural to speak of good fit as the simultaneous satisfaction of a number of requirements, as it will be to call it the simultaneous nonoccurrence of the same number of corresponding misfits.

Let us suppose that we did try to write down a list of all possible relations between a form and its context which were required by good fit. (Such a list would in fact be just the list of requirements which designers often do try to write down.) In theory, we could then use each requirement on the list as an independent criterion, and accept a form as well fitting only if it satisfied all these criteria simultaneously.

However, thought of in this way, such a list of requirements is potentially endless, and still really needs a "field" description to tie it together. Think, for instance, of trying to specify all the properties a button had to have in order to match another. Apart from the kinds of thing we have already mentioned, size, color, number of holes, and so on, we should also have to specify its specific gravity, its electrostatic charge, its viscosity, its rigidity, the fact that it should be round, that it should not be made of paper, etc., etc. In other words, we should not only have to specify the qualities which distinguish it from all other buttons, but we should also have to specify all the characteristics which actually made it a button at all.

Unfortunately, the list of distinguishable characteristics we can write down for the button is infinite. It remains infinite for all practical purposes until we discover a field description of the button. Without the field description of the button, there is no way of reducing the list of required attributes to finite terms. We are therefore forced to economize when we try to specify the nature of a matching button, because we can only grasp a finite list (and rather a short one at that). Naturally, we choose to specify those characteristics which are most likely to cause trouble in the business of matching, and which are therefore most useful in our effort to distinguish among the objects we are likely to come across in our search for buttons. But to do this, we must rely on the fact that a great many objects will not even come up for consideration. There are, after all, conceivable objects which are buttons in every respect except that they carry an electric charge of one thousand coulombs, say. Yet in practice it would be utterly superfluous, as well as rather unwieldy, to specify the electrostatic charge a well-matched button needed to have. No button we are likely to find carries such a charge, so we ignore the possibility. The only reason we are able to match one thing with another at all is that we rely on a good deal of unexpressed information contained in the statement of the task, and take a great deal for granted.[20]

In the case of a design problem which is truly problematical, we encounter the same situation. We do not have a field description of the context, and therefore have no intrinsic way of reducing the potentially infinite set of requirements to finite terms. Yet for practical reasons we do need some way of picking a finite set from the infinite set of possible ones. In the case of requirements, no sensible way of picking this finite set presents itself. From a purely descriptive standpoint we have no way of knowing which of the infinitely many relations between form and context to include, and which ones to leave out.

But if we think of the requirements from a negative point of view, as potential misfits, there is a simple way of picking a finite set. This is because it is through misfit that the problem originally brings itself to our attention. We take just those relations between form and context which obtrude most strongly, which demand attention most clearly, which seem most likely to go wrong. We cannot do better than this.[21] If there were some intrinsic way of reducing the list of requirements to a few, this would mean in essence that we were in possession of a field description of the context: if this were so, the problem of creating fit would become trivial, and no longer a problem of design. We cannot have a unitary or field description of a context and still have a design problem worth attention.

In the case of a real design problem, even our conviction that there is such a thing as fit to be achieved is curiously flimsy and insubstantial. We are searching for some kind of harmony between two intangibles: a form which we have not yet designed, and a context which we cannot properly describe. The only reason we have for thinking that there must be some kind of fit to be achieved between them is that we can detect incongruities, or negative instances of it. The incongruities in an ensemble are the primary data of experience. If we agree to treat fit as the absence of misfits, and to use a list of those potential misfits which are most likely to occur as our criterion for fit, our theory will at least have the same nature as our intuitive conviction that there is a problem to be solved.

The results of this chapter, expressed in formal terms, are these. If we divide an ensemble into form and context, the fit between them may be regarded as an orderly condition of the ensemble, subject to disturbance in various ways, each one a potential misfit. Examples are the misfits between a house and its users, mentioned on page 23. We may summarize the state of each potential misfit by means of a binary variable. If the misfit occurs, we say the variable takes the value 1. If the misfit does not occur, we say the variable takes the value 0. Each binary variable stands for one possible kind of misfit between form and context.[22] The value this variable takes, 0 or 1, describes a state of affairs that is not either in the form alone or in the context alone, but a relation between the two. The state of this relation, fit or misfit, describes one aspect of the whole ensemble. It is a condition of harmony and good fit in the ensemble that none of the possible misfits should actually occur. We represent this fact by demanding that all the variables take the value 0.

The task of design is not to create form which meets certain conditions, but to create such an order in the ensemble that all the variables take the value 0. The form is simply that part of the ensemble over which we have control. It is only through the form that we can create order in the ensemble.

3 / THE SOURCE OF GOOD FIT

We must now try to find out how we should go about getting good fit. Where do we find it? What is the characteristic of processes which create fit successfully?

It has often been claimed in architectural circles that the houses of simpler civilizations than our own are in some sense better than our own houses.[1] While these claims have perhaps been exaggerated, the observation is still sometimes correct. I shall try to show that the facts behind it, if correctly interpreted, are of great practical consequence for an intelligently conceived process of design.

Let us consider a few famous modern houses for a moment, from the point of view of their good fit. Mies Van der Rohe's Farnsworth house, though marvelously clear, and organized under the impulse of certain tight formal rules, is certainly not a triumph economically or from the point of view of the Illinois floods.[2] Buckminster Fuller's geodesic domes have solved the weight problem of spanning space, but you can hardly put doors in them. Again, his dymaxion house, though efficient as a rapid-distribution mass-produced package, takes no account whatever of the incongruity of single free-standing houses set in the acoustic turmoil and service complexity of a modern city.[3] Even Le Corbusier in the Villa Savoie, for example, or in the Marseilles apartments, achieves his clarity of form at the expense of certain elementary comforts and conveniences.[4]

Laymen like to charge sometimes that these designers have sacrificed function for the sake of clarity, because they are out of touch with the practical details of the housewife's world, and preoccupied with their own interests. This is a misleading charge. What is true is that designers do often develop one part of a functional program at the expense of another. But they do it because the only way they seem able to organize form clearly is to design under the driving force of some comparatively simple concept.

On the other hand, if designers do not aim principally at clear organization, but do try to consider all the requirements equally, we find a kind of anomaly at the other extreme. Take the average developer-built house; it is built with an eye for the market, and in a sense, therefore, fits its context well, even if superficially. But in this case the various demands made on the form are met piecemeal, without any sense of the overall organization the form needs in order to contribute as a whole to the working order of the ensemble.

Since everything in the human environment can nowadays be modified by suitable purchases at the five and ten, very little actually has to be taken care of in the house's basic organization. Instead of orienting the house carefully for sun and wind, the builder conceives its organization without concern for orientation, and light, heat, and ventilation are taken care of by fans, lamps, and other kinds of peripheral devices. Bedrooms are not separated from living rooms in plan, but are placed next to one another and the walls between them then stuffed with acoustic insulation.

The complaint that macroscopic clarity is missing in these cases is no aesthetic whim. While it is true that an individual problem can often be solved adequately without regard for the fundamental physical order it implies, we cannot solve a whole net of such problems so casually, and get away with it. It is inconceivable that we should succeed in organizing an ensemble as complex as the modern city until we have a clear enough view of simpler design problems and their implications to produce houses which are physically clear as total organizations.

Yet at present, in our own civilization, house forms which are clearly organized and also satisfactory in all the respects demanded by the context are almost unknown.

If we look at a peasant farmhouse by comparison, or at an igloo, or at an African's mud hut, this combination of good fit and clarity is not quite so hard to find. Take the Mousgoum hut, for instance, built by African tribesmen in the northern section of the French Cameroun.[5] Apart from the variation caused by slight changes in site and occupancy, the huts vary very little. Even superficial examination shows that they are all versions of the same single form type, and convey a powerful sense of their own adequacy and nonarbitrariness.

Whether by coincidence or not, the hemispherical shape of the hut provides the most efficient surface for minimum heat transfer, and keeps the inside reasonably well protected from the heat of the equatorial sun. Its shape is maintained by a series of vertical reinforcing ribs. Besides helping to support the main fabric, these ribs also act as guides for rainwater, and are at the same time used by the builder of the hut as footholds which give him access to the upper part of the outside during its construction.[6] Instead of using disposable scaffolding (wood is very scarce), he builds the scaffolding in as part of the structure. What is more, months later this "scaffolding" is still there when the owner needs to climb up on it to repair the hut. The Mousgoum cannot afford, as we do, to regard maintenance as a nuisance which is best forgotten until it is time to call the local plumber. It is in the same hands as the building operation itself, and its exigencies are as likely to shape the form as those of the initial construction.

Again, each hut nestles beautifully in the dips and hollows of the terrain. It must, because its fabric is as weak structurally as the earth it sits on, and any foreignness or discontinuity caused by careless siting would not have survived the stresses of erosion. The weather-defying concrete foundations which we rely on, and which permit the arbitrary siting of our own houses, are unknown to the Mousgoum.

The grouping of the huts reflects the social order of their inhabitants. Each man's hut is surrounded by the huts of his wives and his subservients, as social customs require — and in such a way, moreover, that these subsidiary huts also form a wall round the chief's hut and thereby protect it and themselves from wild beasts and invaders.[7]

This example shows how the pattern of the building operation, the pattern of the building's maintenance, the constraints of the surrounding conditions, and also the pattern of daily life, are fused in the form. The form has a dual coherence. It is coherently related to its context. And it is physically coherent.

This kind of dual coherence is common in simple cultures. Yet in our own culture the only forms which match these simpler forms for overall clarity of conception are those we have already mentioned, designed under the impulse of very special preoccupations. And these forms, just because they derive their clarity from simplification of the problem, fail to meet all the context's demands.[8] It is true that our functional standards are higher than those in the simple situation. It is true, and important to remember, that the simple cultures never face the problems of complexity which we face in design. And it is true that if they did face them, they would probably not make any better a showing than we do.[9] When we admire the simple situation for its good qualities, this doesn't mean that we wish we were back in the same situation. The dream of innocence is of little comfort to us; our problem, the problem of organizing form under complex constraints, is new and all our own. But in their own way the simple cultures do their simple job better than we do ours. I believe that only careful examination of their success can give us the insight we need to solve the problem of complexity. Let us ask, therefore, where this success comes from.

To answer this question we shall first have to draw a sharp and arbitrary line between those cultures we want to call simple, for the purposes of argument, and those we wish to classify with ours. I propose calling certain cultures unselfconscious, to contrast them with others, including our own, which I propose to call selfconscious.

Of course, the contrast in quality between the forms produced in the two different kinds of culture is by no means as marked as I shall suggest. Nor are the two form-making processes sharply distinguished, as my text pretends. But I have deliberately exaggerated the contrast, simply to draw attention to certain matters, important and illuminating in their own right, which we must understand before we can map out a new approach to design. It is far more important that we should understand the particular contrast I am trying to bring out, than that the facts about any given culture should be accurate or telling. This is not an anthropological treatise, and it is therefore best to think of the first part of the following discussion simply as a comparison of two descriptive constructs, the unselfconscious culture and the selfconscious culture.[10]

The cultures I choose to call "unselfconscious" have, in the past, been called by many other names — each name chosen to illuminate whatever aspect of the contrast between kinds of culture the writer was most anxious to bring out. Thus they have been called "primitive," to distinguish them from those where kinship plays a less important part in social structure;[11] "folk," to set them apart from urban cultures;[12] "closed," to draw attention to the responsibility of the individual in today's more open situation;[13] "anonymous," to distinguish them from cultures in which a profession called "architecture" exists.[14]

The particular distinction I wish to make touches only the last of these: the method of making things and buildings. Broadly, we may distinguish between our own culture, which is very selfconscious about its architecture, art, and engineering, and certain specimen cultures which are rather unselfconscious about theirs.[15] The features which distinguish architecturally unselfconscious cultures from selfconscious ones are easy to describe loosely. In the unselfconscious culture there is little thought about architecture or design as such. There is a right way to make buildings and a wrong way; but while there may be generally accepted remedies for specific failures, there are no general principles comparable to Alberti's treatises or Le Corbusier's. Since the division of labor is very limited, specialization of any sort is rare, there are no architects, and each man builds his own house.[16]

The technology of communication is underdeveloped. There are no written records or architectural drawings, and little intercultural exchange. This lack of written records and lack of information about other cultures and situations means that the same experience has to be won over and over again generation after generation — without opportunity for development or change. With no variety of experience, people have no chance to see their own actions as alternatives to other possibilities, and instead of becoming selfconscious, they simply repeat the patterns of tradition, because these are the only ones they can imagine. In a word, actions are governed by habit.[17] Design decisions are made more according to custom than according to any individual's new ideas. Indeed, there is little value attached to the individual's ideas as such. There is no special market for his inventiveness. Ritual and taboo discourage innovation and self-criticism. Besides, since there is no such thing as "architecture" or "design," and no abstractly formulated problems of design, the kinds of concept needed for architectural self-criticism are too poorly developed to make such self-criticism possible; indeed the architecture itself is hardly tangibly enough conceived as such to criticize.

To be sure that such a distinction between unselfconscious and selfconscious cultures is permissible, we need a definition which will tell us whether to call a culture unselfconscious or selfconscious on the basis of visible and reportable facts alone. We find a clearly visible distinction when we look at the way the crafts of form-building are taught and learned, the institutions under which skills pass from one generation to the next.

For there are essentially two ways in which such education can operate, and they may be distinguished without difficulty.

At one extreme we have a kind of teaching that relies on the novice's very gradual exposure to the craft in question, on his ability to imitate by practice, on his response to sanctions, penalties, and reinforcing smiles and frowns. The great example of this kind of learning is the child's learning of elementary skills, like bicycle riding. He topples almost randomly at first, but each time he does something wrong, it fails; when he happens to do it right, its success and the fact that his success is recognized make him more likely to repeat it right.[18] Extended learning of this kind gives him a "total" feeling for the thing learned — whether it is how to ride a bicycle, or a skill like swimming, or the craft of housebuilding or weaving. The most important feature of this kind of learning is that the rules are not made explicit, but are, as it were, revealed through the correction of mistakes.[19]

The second kind of teaching tries, in some degree, to make the rules explicit. Here the novice learns much more rapidly, on the basis of general "principles." The education becomes a formal one; it relies on instruction and on teachers who train their pupils, not just by pointing out mistakes, but by inculcating positive explicit rules. A good example is lifesaving, where people rarely have the chance to learn by trial and error. In the informal situation there are no "teachers," for the novice's mistakes will be corrected by anybody who knows more than he. But in the formal situation, where learning is a specialized activity and no longer happens automatically, there are distinct "teachers" from whom the craft is learned.[20]

These teachers, or instructors, have to condense the knowledge which was once laboriously acquired in experience, for without such condensation the teaching problem would be unwieldy and unmanageable. The teacher cannot refer explicitly to each single mistake which can be made, for even if there were time to do so, such a list could not be learned. A list needs a structure for mnemonic purposes.[21] So the teacher invents teachable rules within which he accommodates as much of his unconscious training as he can — a set of shorthand principles.

In the unselfconscious culture the same form is made over and over again; in order to learn form-making, people need only learn to repeat a single familiar physical pattern. In the selfconscious culture new purposes are occurring all the time; the people who make forms are constantly required to deal with problems that are either entirely new or at best modifications of old problems. Under these circumstances it is not enough to copy old physical patterns. So that people will be able to make innovations and modifications as required, ideas about how and why things get their shape must be introduced. Teaching must be based on explicit general principles of function, rather than unmentioned and specific principles of shape.

I shall call a culture unselfconscious if its form-making is learned informally, through imitation and correction. And I shall call a culture selfconscious if its form-making is taught academically, according to explicit rules.[22]

Now why are forms made in the selfconscious culture not so well fitting or so clearly made as those in the unselfconscious culture? In one case the form-making process is a good one, in the other bad. What is it that makes a form-making process good or bad?

In explaining why the unselfconscious process is a good one, hardly anyone bothers, nowadays, to argue the myth of the primitive genius, the unsophisticated craftsman supposedly more gifted than his sophisticated counterpart.[23] The myth of architectural Darwinism has taken its place.[24] Yet though this new myth is more acceptable, in its usual form it is not really any more informative than the other.

It says, roughly, that primitive forms are good as a result of a process of gradual adaptation — that over many centuries such forms have gradually been fitted to their cultures by an intermittent though persistent series of corrections. But this explanation is vague hand-waving.[25] It doesn't tell us what it is that prevents such adaptation from taking place successfully in the selfconscious culture, which is what we want to know most urgently. And even as an explanation of good fit in the unselfconscious culture, the raw concept of adaptation is something less than satisfactory. If forms in an unselfconscious culture fit now, the chances are that they always did. We know of no outstanding differences between the present states and past states of unselfconscious cultures; and this assumption, that the fit of forms in such cultures is the result of gradual adjustment (that is, improvement) over time, does not illuminate what must actually be a dynamic process in which both form and context change continuously, and yet stay mutually well adjusted all the time.[26]

To understand the nature of the form-making process, it is not enough to give a quick one-word account of unselfconscious form-making: adaptation. We shall have to compare the detailed inner working of the unselfconscious form-making process with that of the selfconscious process, asking why one works and the other fails. Roughly speaking, I shall argue that the unselfconscious process has a structure that makes it homeostatic (self-organizing), and that it therefore consistently produces well-fitting forms, even in the face of change. And I shall argue that in a selfconscious culture the homeostatic structure of the process is broken down, so that the production of forms which fail to fit their contexts is not only possible, but likely.[27]

We decided in the last chapter that to describe fit and misfit between form and context, we must make a list of binary variables, each naming some one potential misfit which may occur.

Whether a form-making process is selfconscious or unselfconscious, these misfit variables are always present, lingering in the background of the process, as thoughts in a designer's mind, or as actions, criticisms, failures, doubts. Only the thought or the experience of possible failure provides the impetus to make new form.

At any moment in a form-making process, whether the form is in use, a prototype, as yet only a sketch, or obsolete, each of the variables is in a state of either fit or misfit. We may describe the state of all the variables at once by a row of 1's and 0's, one for each variable: for instance, for twenty variables, 00100110101110110000 would be one state. Each possible row of 1's and 0's is a possible state of the ensemble.

As form-making proceeds, so the system of variables changes state. One misfit is eradicated, another misfit occurs, and these changes in their turn set off reactions within the system that affect the states of other variables. As form and culture change, state follows state. The sequence of states which the system passes through is a record or history of the adaptation between form and context. The history of the system displays the form-making process at work. To compare unselfconscious and selfconscious form-making processes, we have only to examine the kinds of history which the system of variables can have in these two processes. As we shall see, the kinds of history which the system can have in the unselfconscious and selfconscious processes are very different.

We shall perhaps understand the idea of a system's history best if we make a simple picture of it.[28]

Imagine a system of a hundred lights. Each light can be in one of two possible states. In one state the light is on. The lights are so constructed that any light which is on always has a 50–50 chance of going off in the next second. In the other state the light is off. Connections between lights are constructed so that any light which is off has a 50–50 chance of going on again in the next second, provided at least one of the lights it is connected to is on. If the lights it is directly connected to are off, for the time being it has no chance of going on again, and stays off. If the lights are ever all off simultaneously, then they will all stay off for good, since when no light is on, none of the lights has any chance of being reactivated. This is a state of equilibrium. Sooner or later the system of lights will reach it.

This system of lights will help us understand the history of a form-making process. Each light is a binary variable, and so may be thought of as a misfit variable. The off state corresponds to fit; the on state corresponds to misfit. The fact that a light which is on has a 50–50 chance of going off every second, corresponds to the fact that whenever a misfit occurs efforts are made to correct it. The fact that lights which are off can be turned on again by connected lights, corresponds to the fact that even well-fitting aspects of a form can be unhinged by changes initiated to correct some other misfit because of connections between variables. The state of equilibrium, when all the lights are off, corresponds to perfect fit or adaptation. It is the equilibrium in which all the misfit variables take the value 0. Sooner or later the system of lights will always reach this equilibrium. The only question that remains is, how long will it take for this to happen? It is not hard to see that apart from chance this depends only on the pattern of interconnections between the lights.

Let us consider two extreme circumstances.[29]

1. On the one hand, suppose there are no interconnections between lights at all. In this case there is nothing to prevent each light's staying off for good, as soon as it goes off. The average time it takes for all the lights to go off is therefore only a little greater than the average time it takes for a single light to go off, namely 2^1 seconds or 2 seconds.

2. On the other hand, imagine such rich interconnections between lights that any one light still on quickly rouses all others from the off state and puts them on again. The only way in which this system can reach adaptation is by the pure chance that all 100 happen to go off at the same moment. The average time which must elapse before this happens will be of the order of 2^{100} seconds, or 10^{22} years.

The second case is useless. The age of the universe itself is only about 10^{10} years. For all intents and purposes the system will never adapt. But the first case is no use either. In any real system there are interconnections between variables which make it impossible for each variable to adapt in complete isolation. Let us therefore construct a third possibility.

3. In this case suppose there are again interconnections among the 100 lights, but that we discern in the pattern of interconnections some 10 principal subsystems, each containing 10 lights.[30] The lights within each subsystem are so strongly connected to one another that again all 10 must go off simultaneously before they will stay off; yet at the same time the subsystems themselves are independent of one another as wholes, so that the lights in one subsystem can be switched off without being reactivated by others flashing in other subsystems. The average time it will take for all 100 lights to go off is about the same as the time it takes for one subsystem to go off, namely 2^{10} seconds, or about a quarter of an hour.

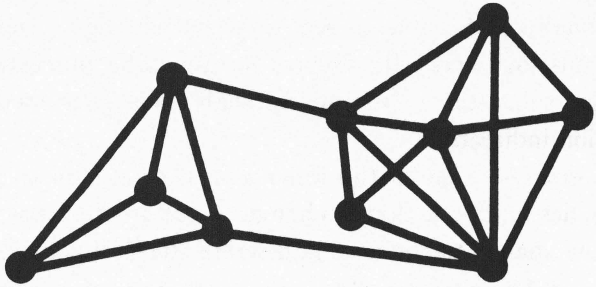
Of course, real systems do not behave so simply. But fifteen minutes is not much greater than the two seconds it takes an isolated variable to adapt, and the enormous gap between these magnitudes and 10^{22} years does teach us a vital lesson. No complex adaptive system will succeed in adapting in a reasonable amount of time unless the adaptation can proceed subsystem by subsystem, each subsystem relatively independent of the others.[31]

This is a familiar fact. It finds a close analogy in the children's sealed glass-fronted puzzles which are such fun and so infuriating. The problem, in these puzzles, is to achieve certain configurations within the box: rings on sticks, balls in sockets, pieces of various shapes in odd-shaped frames — but all to be done by gentle tapping on the outside of the box. Think of the simplest of these puzzles, where half a dozen colored beads, say, are each to be put in a hole of corresponding color.

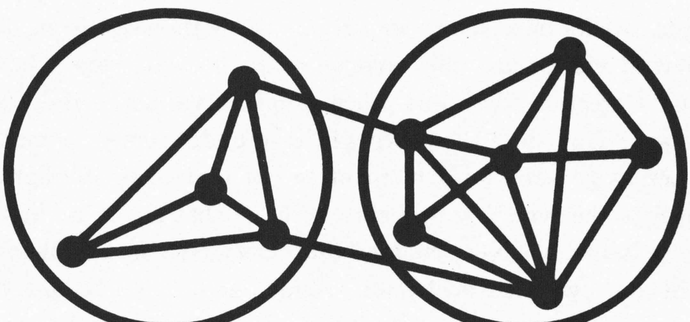
One way to go about this problem would be to pick the puzzle up, give it a single energetic shake, and lay it down again, in the hope that the correct configuration would appear by accident. This all-or-nothing method might be repeated many thousand times, but it is clear that its chances of success are negligible. It is the technique of a child who does not understand how best to play. Much the easiest way — and the way we do in fact adopt under such circumstances — is to juggle one bead at a time. Once a bead is in, provided we tap gently, it is in for good, and we are free to manipulate the next one that presents itself, and we achieve the full configuration step by step. When we treat each bead as an isolable subsystem, and take the subsystems independently, we can solve the puzzle.

If we now consider the process of form-making, in the light of these examples, we see an easy way to make explicit the distinction between processes which work and those which don't.

Let us remind ourselves of the precise sense in which there is a system active in a form-making process. It is a purely fictitious system. Its variables are the conditions which must be met by good fit between form and context. Its interactions are the causal linkages which connect the variables to one another. If there is not enough light in a house, for instance, and more windows are added to correct this failure, the change may improve the light but allow too little privacy; another change for more light makes the windows bigger, perhaps, but thereby makes the house more likely to collapse. These are examples of inter-variable linkage. If we represent this system by drawing a point for each misfit variable, and a link between two points for each such causal linkage, we get a structure which looks something like this:



Now, let us go back to the question of adaptation. Clearly these misfit variables, being interconnected, cannot adjust independently, one by one. On the other hand, since not all the variables are equally strongly connected (in other words there are not only dependences among the variables, but also *independences*), there will always be subsystems like those circled below, which can, in principle, operate fairly independently.[32]



We may therefore picture the process of form-making as the action of a series of subsystems, all interlinked, yet sufficiently free of one another to adjust independently in a feasible amount of time. It works, because the cycles of correction and recorrection, which occur during adaptation, are restricted to one subsystem at a time.

We shall not be able to see, directly, whether or not the unselfconscious and selfconscious form-making processes operate by subsystems. Instead we shall infer their modes of operation indirectly.

The greatest clue to the inner structure of any dynamic process lies in its reaction to change. A culture does not move from one change to the next in discrete steps, of course. New threads are being woven all the time, making changes continuous and smooth. But from the point of view of its effect on a form, change only becomes significant at that moment when a failure or misfit reaches critical importance — at that moment when it is recognized, and people feel the form has something wrong with it. It is therefore legitimate, for our purpose, to consider a culture as changing in discrete steps.[33]

We wish to know, now, how the form-making process reacts to one such change. Whether a new, previously unknown misfit occurs or a known one recurs, in both cases, from our point of view, some one variable changes value from 0 to 1. What, precisely, happens when a misfit variable takes the value 1? How does the process behave under this stimulus?

Let us go back for a moment to our system of 100 lights. Suppose the system is in a state of fit — that is, all the lights are switched off. Now imagine that every once in a while one light gets switched on by an outside agent, even though no others are on to activate it. By waiting to see what happens next, we can very easily deduce the inner nature of the system, even though we cannot see it directly. If the light always flashes just once, and then goes off again and stays off, we deduce that the lights are able to adapt independently, and hence that there are no interconnections between lights. If the light activates a few other lights, and they flash together for a while, and then switch themselves off, we deduce that there are subsystems of interconnected lights active. If the light flashes and then activates other lights until all of them are flashing, and they never settle down again, we deduce that the system is unable to adapt subsystem by subsystem because the interconnections are too rich.

The solitary light switched on by an external agent is the occasional misfit which occurs. The reaction of the system to the disturbance is the reaction of the form-making process to the misfit. If we detect the active presence of subsystems in a process, we may then argue (by induction, as it were) that this is fully responsible for the good fit of the forms being produced by the process. For if good forms can always be adjusted correctly the moment any slight misfit occurs, then no sequence of changes will destroy the good fit ever (at least while the process maintains this character); and provided there was good fit at some stage in the past, no matter how remote (the first term of the induction), it will have persisted, because there is an active stability at work.[34] If, on the other hand, a form-making process is such that a minor culture change can upset the good fit of the forms it produces, then any well-fitting forms we may observe at one time or another fit only by accident; and the next cultural deflection may once more lead to the production of badly fitting forms.

It is the inner nature of the process which counts. The vital point that underlies the following discussion is that the form-builders in unselfconscious cultures respond to small changes in a way that allows the subsystems of the misfit system to work independently — but that because the selfconscious response to change cannot take place subsystem by subsystem, its forms are arbitrary.

4 / THE UNSELFCONSCIOUS PROCESS

Let us turn our attention, first of all, to the unselfconscious cultures. It will be necessary first to outline the conditions under which forms in unselfconscious cultures are produced. We know by definition that building skills are learned informally, without the help of formulated rules.[1] However, although there are no formulated rules (or perhaps indeed, as we shall see later, just because there are none), the unspoken rules are of great complexity, and are rigidly maintained. There is a way to do things, a way not to do them. There is a firmly set tradition, accepted beyond question by all builders of form, and this tradition strongly resists change.

The existence of such powerful traditions, and evidence of their rigidity, already are shown to some extent in those aspects of unselfconscious cultures which have been discussed. It is clear, for instance, that forms do not remain the same for centuries without traditions springing up about them. If the Egyptian houses of the Nile have the same plan now as the houses whose plans were pictured in the hieroglyphs,[2] we can be fairly certain that their makers are in the grip of a tradition. Anywhere where forms are virtually the same now as they were thousands of years ago, the bonds must be extremely strong. In southern Italy, neither the *trulli* of Apulia nor the coalburners' *capanne* of Anzio near Rome have changed since prehistoric times.[3] The same is known to be true of the black houses of the Outer Hebrides, and of the hogans of the Navaho.[4]

The most visible feature of architectural tradition in such unselfconscious cultures is the wealth of myth and legend attached to building habits. While the stories rarely deal exclusively with dwellings, nevertheless descriptions of the house, its form, its origins, are woven into many of the global myths which lie at the very root of culture; and wherever this occurs, not only is the architectural tradition made unassailable, but its constant repetition is assured. The black tents, for example, common among nomads from Tunisia to Afghanistan, figure more than once in the Old Testament.[5] In a similar way the folk tales of old Ireland and the Outer Hebrides are full of oblique references to the shape of houses.[6] The age of these examples gives us an inkling of the age and strength of the traditions which maintain the shape of unselfconscious dwelling forms. Wherever the house is mentioned in a myth or lore, it at once becomes part of the higher order, ineffable, immutable, not to be changed. When certain Indians of the Amazon believe that after death the soul retires to a house at the source of a mysterious river,[7] the mere association of the house with a story of this kind discourages all thoughtful criticism of the standard form, and sets its "rightness" well beyond the bounds of question.

More forceful still, of course, are rituals and taboos connected with the dwelling. Throughout Polynesia the resistance to change makes itself felt quite unequivocally in the fact that the building of a house is a ceremonial occasion.[8] The performance of the priests, and of the workers, though different from one island to the next, is always clearly specified; and the rigidity of these behavior patterns, by preserving techniques, preserves the forms themselves and makes change extremely difficult. The Navaho Indians, too, make their hogans the center of the most elaborate performance.[9] Again the gravity of the rituals, and their rigidity, make it impossible that the form of the hogan should be lightly changed.

The rigidity of tradition is at its clearest, though, in the case where builders of form are forced to work within definitely given limitations. The Samoan, if he is to make a good house, must use wood from the breadfruit tree.[10] The Italian peasant making his *trullo* at Alberobello is allowed latitude for individual expression only in the lump of plaster which crowns the cone of the roof.[11] The Wanoe has a chant which tells him precisely the sequence of operations he is to follow while building his house.[12] The Welshman must make the crucks which support his roof precisely according to the pattern of tradition.[13] The Sumatran gives his roofs their special shape, not because this is structurally essential, but because this is the way to make roofs in Sumatra.[14]

Every one of these examples points in the same direction. Unselfconscious cultures contain, as a feature of their form-producing systems, a certain built-in fixity — patterns of myth, tradition, and taboo which resist willful change. Form-builders will only introduce changes under strong compulsion where there are powerful (and obvious) irritations in the existing forms which demand correction.

Now when there are such irritations, how fast does the failure lead to action, how quickly does it lead to a change of form? Think first, perhaps, of man's closeness to the ground in the unselfconscious culture, and of the materials he uses when he makes his house. The Hebridean crofter uses stone and clay and sods and grass and straw, all from the near surroundings.[15] The Indian's tent used to be made of hide from the buffalo he ate.[16] The Apulian uses as building stones the very rocks which he has taken from the ground to make his agriculture possible.[17] These men have a highly developed eye for the trees and stones and animals which contain the means of their livelihood, their food, their medicine, their furniture, their tools. To an African tribesman the materials available are not simply objects, but are full of life.[18] He knows them through and through; and they are always close to hand.

Closely associated with this immediacy is the fact that the owner is his own builder, that the form-maker not only makes the form but lives in it. Indeed, not only is the man who lives in the form the one who made it, but there is a special closeness of contact between man and form which leads to constant rearrangement of unsatisfactory detail, constant improvement. The man, already responsible for the original shaping of the form, is also alive to its demands while he inhabits it.[19] And anything which needs to be changed is changed at once.

The Abipon, whose dwelling was the simplest tent made of two poles and a mat, dug a trench to carry off the rain if it bothered him.[20] The Eskimo reacts constantly to every change in temperature inside the igloo by opening holes or closing them with lumps of snow.[21] The very special directness of these actions may be made clearer, possibly, as follows. Think of the moment when the melting snow dripping from the roof is no longer bearable, and the man goes to do something about it. He makes a hole which lets some cold air in, perhaps. The man realizes that he has to do something about it — but he does not do so by remembering the general rule and then applying it ("When the snow starts to melt it is too hot inside the igloo and therefore time to . . ."). He simply does it. And though words may accompany his action, they play no essential part in it. This is the important point. The failure or inadequacy of the form leads directly to the action.

This directness is the second crucial feature of the unselfconscious system's form-production. Failure and correction go side by side. There is no deliberation in between the recognition of a failure and the reaction to it.[22] The directness is enhanced, too, by the fact that building and repair are so much an everyday affair. The Eskimo, on winter hunts, makes a new igloo every night.[23] The Indian's tepee cover rarely lasts more than a single season.[24] The mud walls of the Tallensi hut need frequent daubs.[25] Even the elaborate communal dwellings of the Amazon tribes are abandoned every two or three years, and new ones built.[26] Impermanent materials and unsettled ways of life demand constant reconstruction and repair, with the result that the shaping of form is a task perpetually before the dweller's eyes and hands. If a form is made the same way several times over, or even simply left unchanged, we can be fairly sure that its inhabitant finds little wrong with it. Since its materials are close to hand, and their use his own responsibility, he will not hesitate to act if there are any minor changes which seem worth making.

Let us return now to the question of adaptation. The basic principle of adaptation depends on the simple fact that the process toward equilibrium is irreversible. Misfit provides an incentive to change; good fit provides none. In theory the process is eventually bound to reach the equilibrium of well-fitting forms.

However, for the fit to occur in practice, one vital condition must be satisfied. It must have time to happen. The process must be able to achieve its equilibrium before the next culture change upsets it again. It must actually have time to reach its equilibrium every time it is disturbed — or, if we see the process as continuous rather than intermittent, the adjustment of forms must proceed more quickly than the drift of the culture context. Unless this condition is fulfilled the system can never produce well-fitting forms, for the equilibrium of the adaptation will not be sustained.

As we saw in Chapter 3, the speed of adaptation depends essentially on whether the adaptation can take place in independent and restricted subsystems, or not. Although we cannot actually see these subsystems in the unselfconscious process, we can infer their activity from the very two characteristics of the process which we have been discussing: directness and tradition.

The direct response is the feedback of the process.[27] If the process is to maintain the good fit of dwelling forms while the culture drifts, it needs a feedback sensitive enough to take action the moment that one of the potential failures actually occurs. The vital feature of the feedback is its immediacy. For only through prompt action can it prevent the build-up of multiple failures which would then demand simultaneous correction — a task which might, as we have seen, take too long to be feasible in practice.

However, the sensitivity of feedback is not in itself enough to lead to equilibrium. The feedback must be controlled, or damped, somehow.[28] Such control is provided by the resistance to change the unselfconscious culture has built into its traditions. We might say of these traditions, possibly, that they make the system viscous. This viscosity damps the changes made, and prevents their extension to other aspects of the form. As a result only urgent changes are allowed. Once a form fits well, changes are not made again until it fails to fit again. Without this action of tradition, the repercussions and ripples started by the slightest failure could grow wider and wider until they were spreading too fast to be corrected.

On the one hand the directness of the response to misfit ensures that each failure is corrected as soon as it occurs, and thereby restricts the change to one subsystem at a time. And on the other hand the force of tradition, by resisting needless change, holds steady all the variables not in the relevant subsystem, and prevents those minor disturbances outside the subsystem from taking hold. Rigid tradition and immediate action may seem contradictory. But it is the very contrast between these two which makes the process self-adjusting. It is just the fast reaction to single failures, complemented by resistance to all other change, which allows the process to make series of minor adjustments instead of spasmodic global ones: it is able to adjust subsystem by subsystem, so that the process of adjustment is faster than the rate at which the culture changes; equilibrium is certain to be re-established whenever slight disturbances occur; and the forms are not simply well-fitted to their cultures, but in active equilibrium with them.[29]

The operation of such a process hardly taxes the individual craftsman's ability at all. The man who makes the form is an agent simply, and very little is required of him during the form's development. Even the most aimless changes will eventually lead to well-fitting forms, because of the tendency to equilibrium inherent in the organization of the process.

All the agent need do is to recognize failures when they occur, and to react to them. And this even the simplest man can do. For although only few men have sufficient integrative ability to invent form of any clarity, we are all able to criticize existing forms.[30] It is especially important to understand that the agent in such a process needs no creative strength. He does not need to be able to improve the form, only to make some sort of change when he notices a failure. The changes may not be always for the better; but it is not necessary that they should be, since the operation of the process allows only the improvements to persist.

To make the foregoing analysis quite clear, I shall use it to illuminate a rather curious phenomenon.[31] The Slovakian peasants used to be famous for the shawls they made. These shawls were wonderfully colored and patterned, woven of yarns which had been dipped in homemade dyes. Early in the twentieth century aniline dyes were made available to them. And at once the glory of the shawls was spoiled; they were now no longer delicate and subtle, but crude. This change cannot have come about because the new dyes were somehow inferior. They were as brilliant, and the variety of colors was much greater than before. Yet somehow the new shawls turned out vulgar and uninteresting.

Now if, as it is so pleasant to suppose, the shawlmakers had had some innate artistry, had been so gifted that they were simply "able" to make beautiful shawls, it would be almost impossible to explain their later clumsiness. But if we look at the situation differently, it is very easy to explain. The shawlmakers were simply able, as many of us are, to recognize *bad* shawls, and their own mistakes.

Over the generations the shawls had doubtless often been made extremely badly. But whenever a bad one was made, it was recognized as such, and therefore not repeated. And though nothing is to say that the change made would be for the better, it would still be a change. When the results of such changes were still bad, further changes would be made. The changes would go on until the shawls were good. And only at this point would the incentive to go on changing the patterns disappear.

So we do not need to pretend that these craftsmen had special ability. They made beautiful shawls by standing in a long tradition, and by making minor changes whenever something seemed to need improvement. But once presented with more complicated choices, their apparent mastery and judgment disappeared. Faced with the complex unfamiliar task of actually inventing forms from scratch, they were unsuccessful.

5 / THE SELFCONSCIOUS PROCESS

In the unselfconscious culture a clear pattern has emerged. Being self-adjusting, its action allows the production of well-fitting forms to persist in active equilibrium with the system.

The way forms are made in the selfconscious culture is very different. I shall try to show how, just as it is a property of the unselfconscious system's organization that it produces well-fitting forms, so it is a property of the emergent self-conscious system that its forms fit badly.

In one way it is easy enough to see what goes wrong with the arrival of selfconsciousness. The very features which we have found responsible for stability in the unselfconscious process begin to disappear.

The reaction to failure, once so direct, now becomes less and less direct. Materials are no longer close to hand. Buildings are more permanent, frequent repair and readjustment less common, than they used to be. Construction is no longer in the hands of the inhabitants; failures, when they occur, have to be several times reported and described before the specialist will recognize them and make some permanent adjustment. Each of these changes blunts the hair-fine sensitivity of the unselfconscious process' response to failure, so that failures now need to be quite considerable before they will induce correction.

The firmness of tradition too, dissolves. The resistance to willful change weakens, and change for its own sake becomes acceptable. Instead of forms being held constant in all respects but one, so that correction can be immediately effective, the interplay of simultaneous changes is now uncontrolled. To put it playfully, the viscosity which brought the unselfconscious process to rest when there were no failures left, is thinned by the high temperature of selfconsciousness. And as a result the system's drive to equilibrium is no longer irreversible; any equilibrium the system finds will not now be sustained; those aspects of the process which could sustain it have dropped away.

In any case, the culture that once was slow-moving, and allowed ample time for adaptation, now changes so rapidly that adaptation cannot keep up with it. No sooner is adjustment of one kind begun than the culture takes a further turn and forces the adjustment in a new direction. No adjustment is ever finished. And the essential condition on the process — that it should in fact have time to reach its equilibrium — is violated.

This has all actually happened. In our own civilization, the process of adaptation and selection which we have seen at work in unselfconscious cultures has plainly disappeared. But that is not in itself enough to account for the fact that the selfconscious culture does not manage to produce clearly organized, well-fitting forms in its own way. Though we may easily be right in putting our present unsuccess down to our selfconsciousness, we must find out just what it is about selfconscious form-production that causes trouble. The pathology of the selfconscious culture is puzzling in its own right, and is not to be explained simply by the passing of the unselfconscious process.

I do not wish to imply here that there is any unique process of development that makes selfconscious cultures out of unselfconscious ones. Let us remember anyway that the distinction between the two is artificial. And, besides, the facts of history suggest that the development from one to the other can happen in rather different ways.[1] From the point of view of my present argument it is immaterial how the development occurs. All that matters, actually, is that sooner or later the phenomenon of the master craftsman takes control of the form-making activities.

One example, of an early kind, of developing selfconsciousness is found in Samoa. Although ordinary Samoan houses are built by their inhabitants-to-be, custom demands that guest houses be built exclusively by carpenters.[2] Since these carpenters need to find clients, they are in business as artists; and they begin to make personal innovations and changes for no reason except that prospective clients will judge their work for its inventiveness.[3]

The form-maker's assertion of his individuality is an important feature of selfconsciousness. Think of the willful forms of our own limelight-bound architects. The individual, since his livelihood depends on the reputation he achieves, is anxious to distinguish himself from his fellow architects, to make innovations, and to be a star.[4]

The development of architectural individualism is the clearest manifestation of the moment when architecture first turns into a selfconscious discipline. And the selfconscious architect's individualism is not entirely willful either. It is a natural consequence of a man's decision to devote his life exclusively to the one activity called "architecture."[5] Clearly it is at this stage too that the activity first becomes ripe for serious thought and theory. Then, with architecture once established as a discipline, and the individual architect established, entire institutions are soon devoted exclusively to the study and development of design. The academies are formed. As the academies develop, the unformulated precepts of tradition give way to clearly formulated concepts whose very formulation invites criticism and debate.[6] Question leads to unrest, architectural freedom to further selfconsciousness, until it turns out that (for the moment anyway) the form-maker's freedom has been dearly bought. For the discovery of architecture as an independent discipline costs the form-making process many fundamental changes. Indeed, in the sense I shall now try to describe, architecture did actually fail from the very moment of its inception. With the invention of a teachable discipline called "architecture," the old process of making form was adulterated and its chances of success destroyed.

The source of this trouble lies with the individual. In the unselfconscious system the individual is no more than an agent.[7] He does what he knows how to do as best he can. Very little demand is made of him. He need not himself be able to invent forms at all. All that is required is that he should recognize misfits and respond to them by making minor changes. It is not even necessary that these changes be for the better. As we have seen, the system, being self-adjusting, finds its own equilibrium — provided only that misfit incites *some* reaction in the craftsman. The forms produced in such a system are not the work of individuals, and their success does not depend on any one man's artistry, but only on the artist's place within the process.[8]

The selfconscious process is different. The artist's selfconscious recognition of his individuality has deep effect on the process of form-making. Each form is now seen as the work of a single man, and its success is his achievement only. Selfconsciousness brings with it the desire to break loose, the taste for individual expression, the escape from tradition and taboo, the will to self-determination. But the wildness of the desire is tempered by man's limited invention. To achieve in a few hours at the drawing board what once took centuries of adaptation and development, to invent a form suddenly which clearly fits its context — the extent of the invention necessary is beyond the average designer.

A man who sets out to achieve this adaptation in a single leap is not unlike the child who shakes his glass-topped puzzle fretfully, expecting at one shake to arrange the bits inside correctly.[9] The designer's attempt is hardly random as the child's is; but the difficulties are the same. *His chances of success are small because the number of factors which must fall simultaneously into place is so enormous.*

Now, in a sense, the limited capacity of the individual designer makes further treatment of the failure of selfconsciousness superfluous. If the selfconscious culture relies on the individual to produce its forms, and the individual isn't up to it, there seems nothing more to say. But it is not so simple. The individual is not merely weak. The moment he becomes aware of his own weakness in the face of the enormous challenge of a new design problem, he takes steps to overcome his weakness; and strangely enough these steps themselves exert a very positive bad influence on the way he develops forms. In fact, we shall see that the selfconscious system's lack of success really doesn't lie so much in the individual's lack of capacity as in the kind of efforts he makes, when he is selfconscious, to overcome this incapacity.

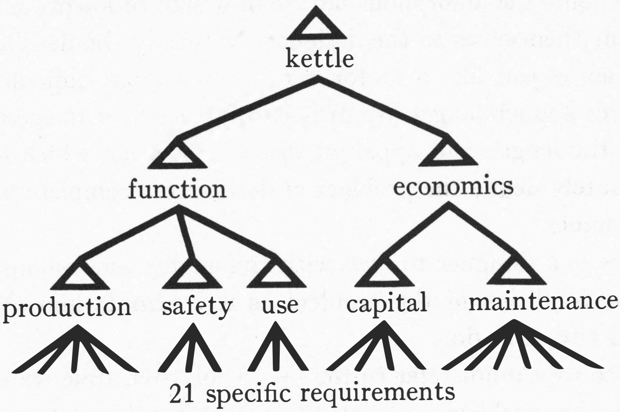
Let us look again at just what kind of difficulty the designer faces. Take, for example, the design of a simple kettle. He has to invent a kettle which fits the context of its use. It must not be too small. It must not be hard to pick up when it is hot. It must not be easy to let go of by mistake. It must not be hard to store in the kitchen. It must not be hard to get the water out of. It must pour cleanly. It must not let the water in it cool too quickly. The material it is made of must not cost too much. It must be able to withstand the temperature of boiling water. It must not be too hard to clean on the outside. It must not be a shape which is too hard to machine. It must not be a shape which is unsuitable for whatever reasonably priced metal it is made of. It must not be too hard to assemble, since this costs man-hours of labor. It must not corrode in steamy kitchens. Its inside must not be too difficult to keep free of scale. It must not be hard to fill with water. It must not be uneconomical to heat small quantities of water in, when it is not full. It must not appeal to such a minority that it cannot be manufactured in an appropriate way because of its small demand. It must not be so tricky to hold that accidents occur when children or invalids try to use it. It must not be able to boil dry and burn out without warning. It must not be unstable on the stove while it is boiling.

I have deliberately filled a page with the list of these twenty-one detailed requirements or misfit variables so as to bring home the amorphous nature of design problems as they present themselves to the designer. Naturally the design of a complex object like a motor car is much more difficult and requires a much longer list. It is hardly necessary to speculate as to the length and apparent disorder of a list which could adequately define the problem of designing a complete urban environment.

How is a designer to deal with this highly amorphous and diffuse condition of the problem as it confronts him? What would any of us do?

Since we cannot refer to the list in full each time we think about the problem, we invent a shorthand notation. We classify the items, and then think about the names of the classes: since there are fewer of these, we can think about them much more easily. To put it in the language of psychology, there are limits on the number of distinct concepts which we can manipulate cognitively at any one time, and we are therefore forced, if we wish to get a view of the whole problem, to re-encode these items.[10] Thus, in the case of the kettle, we might think about the class of requirements generated by the process of the kettle's manufacture, its capacity, its safety requirements, the economics of heating water, and its good looks. Each of these concepts is a general name for a number of the specific requirements. If we were in a very great hurry (or for some reason wanted to simplify the problem even further), we might even classify these concepts in turn, and deal with the problem simply in terms of (1) its function and (2) its economics. In this case we would have erected a four-level hierarchy like that in the diagram on the next page.

By erecting such a hierarchy of concepts for himself, the



designer is, after all, able to face the problem all at once. He achieves a powerful economy of thought, and can by this means thread his way through far more difficult problems than he could cope with otherwise. If hierarchies seem less common in practice than I seem to suggest, we have only to look at the contents of any engineering manual or architects' catalogue; the hierarchy of chapter headings and subheadings is organized the way it is, precisely for cognitive convenience.[11]

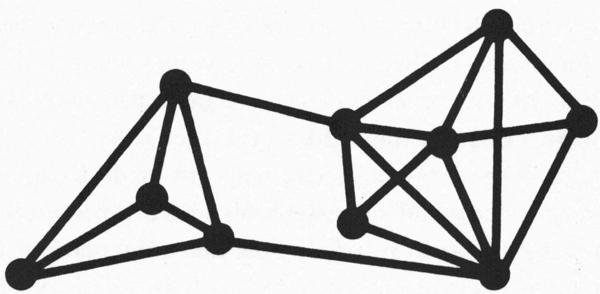
To help himself overcome the difficulties of complexity, the designer tries to organize his problem. He classifies its various aspects, thereby gives it shape, and makes it easier to handle. What bothers him is not only the difficulty of the problem either. The constant burden of decision which he comes across, once freed from tradition, is a tiring one. So he avoids it where he can by using rules (or general principles), which he formulates in terms of his invented concepts. These principles are at the root of all so-called "theories" of architectural design.[12] They are prescriptions which relieve the burden of selfconsciousness and of too much responsibility.

It is rash, perhaps, to call the invention of either concepts or prescriptions a conscious attempt to simplify problems. In practice they unfold as the natural outcome of critical discussion about design. In other words, the generation of verbal concepts and rules need not only be seen abstractly as the supposed result of the individual's predicament, but may be observed wherever the kind of formal education we have called selfconscious occurs.

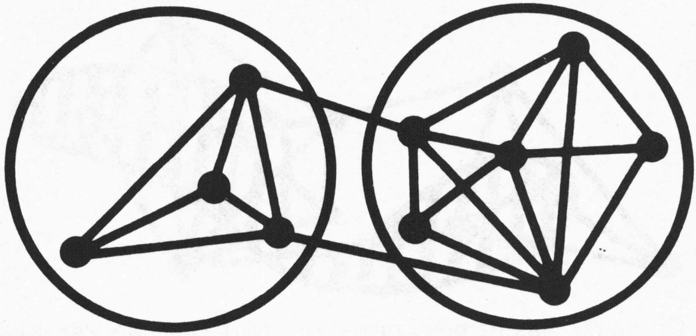
A novice in the unselfconscious situation learns by being put right whenever he goes wrong. "No, not that way, this way." No attempt is made to formulate abstractly just what the right way involves. The right way is the residue when all the wrong ways are eradicated. But in an intellectual atmosphere free from the inhibition of tradition, the picture changes. The moment the student is free to question what he is told, and value is put on explanation, it becomes important to decide why "this" is the right way rather than "that," and to look for general reasons. Attempts are made to aggregate the specific failures and successes which occur, into principles. And each such general principle now takes the place of many separate and specific admonitions. It tells us to avoid this kind of form, perhaps, or praises that kind. With failure and success defined, the training of the architect develops rapidly. The huge list of specific misfits which can occur, too complex for the student to absorb abstractly and for that reason usually to be grasped only through direct experience, as it is in the unselfconscious culture, *can* now be learned — because it has been given form. The misfit variables are patterned into categories like "economics" or "acoustics." And condensed, like this, they can be taught, discussed, and criticized. It is this point, where these concept-determined principles begin to figure in the training and practice of the architect, that the ill-effect of selfconsciousness on form begins to show itself.

I shall now try to draw attention to the peculiar and damaging arbitrariness of the concepts which are invented. Let us remember that the system of interdependent requirements or misfit variables active in the unselfconscious ensemble is still present underneath the surface.

Suppose, as before, we picture the system crudely by drawing a link between every pair of interdependent requirements: we get something that looks like this.



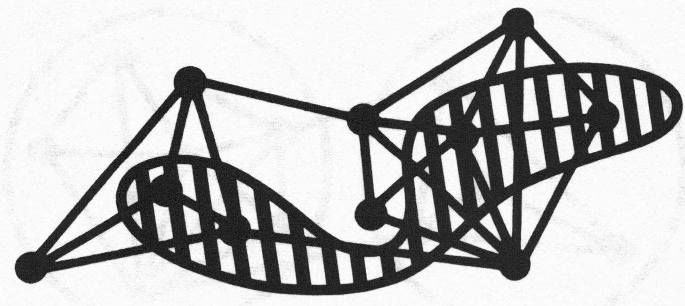
As we have seen before, the variables of such a system can be adjusted to meet the specified conditions in a reasonable time only if its subsystems are adjusted independently of one another. A subsystem, roughly speaking, is one of the obvious components of the system, like the parts shown with a circle round them. If we try to adjust a set of variables which does not constitute a subsystem, the repercussions of the adjustment affect others outside the set, because the set is not sufficiently independent. What we saw in Chapter 4, effectively, was that the procedure of the unselfconscious system is so



organized that adjustment *can* take place in each one of these subsystems independently. This is the reason for its success.

In the selfconscious situation, on the other hand, the designer is faced with all the variables simultaneously. Yet we know from the simple computation on page 40 that if he tries to manipulate them all at once he will not manage to find a well-fitting form in any reasonable time. When he himself senses this difficulty, he tries to break the problem down, and so invents concepts to help himself decide which subsets of requirements to deal with independently. Now what are these concepts, in terms of the system of variables? Each concept identifies a certain collection of the variables. "Economics" identifies one part of the system, "safety" another, "acoustics" another, and so on.

My contention is this. These concepts will not help the designer in finding a well-adapted solution unless they happen to correspond to the system's subsystems. But since the concepts are on the whole the result of arbitrary historical accidents, there is no reason to expect that they will in fact correspond to these subsystems. They are just as likely to identify any other parts of the system, like this:



Of course this demonstrates only that concepts *can* easily be arbitrary. It does not show that the concepts used in practice actually are so. Indeed, clearly, their arbitrariness can only be established for individual and specific cases. Detailed analysis of the problem of designing urban family houses, for instance, has shown that the usually accepted functional categories like acoustics, circulation, and accommodation are inappropriate for this problem.[13] Similarly, the principle of the "neighborhood," one of the old chestnuts of city-planning theory, has been shown to be an inadequate mental component of the residential planning problem.[14] But since such demonstrations can only be made for special cases, let us examine a more general, rather plausible reason for believing that such verbal concepts always will be of this arbitrary kind.

Every concept can be defined and understood in two complementary ways. We may think of it as the name of a class of objects or subsidiary concepts; or we may think of what it means. We define a concept *in extension* when we specify all the elements of the class it refers to. And we define a concept *in intension* when we try to explain its meaning analytically in terms of other concepts at the same level.[15]

For the sake of argument I have just been treating terms like "acoustics" as class names, as a collective way of talking about a number of more specific requirements. The "neighborhood," too, though less abstract and more physical, is still a concept which summarizes mentally all those specific requirements, like primary schooling, pedestrian safety, and community, which a physical neighborhood is supposed to meet. In other words, each of the concepts "acoustics" and "neighborhood" is a variable whose value extension is the same as that given by the conjunction of all the value extensions of the specific acoustic variables, or the specific community-living variables, respectively.[16] This extensional view of the concept is convenient for the sake of mathematical clarity. But in practice, as a rule, concepts are not generated or defined in extension; they are generated in intension. That is, we fit new concepts into the pattern of everyday language by relating their meanings to those of other words at present available in English.

Yet this part played by language in the invention of new concepts, though very important from the point of view of communication and understanding, is almost entirely irrelevant from the point of view of a problem's structure.[17] The demand that a new concept be definable and comprehensible is important from the point of view of teaching and self-conscious design. Take the concept "safety," for example. Its existence as a common word is convenient and helps hammer home the very general importance of keeping designs danger-free. But it is used in the statement of such dissimilar problems as the design of a tea kettle and the design of a highway interchange. As far as its meaning is concerned it is relevant to both. But as far as the individual structure of the two problems goes, it seems unlikely that the one word should successfully identify a principal component subsystem in each of these two very dissimilar problems. Unfortunately, although every problem has its own structure, and there are many different problems, the words we have available to describe the components of these problems are generated by forces in the language, not by the problems, and are therefore rather limited in number and cannot describe more than a few cases correctly.[18]

Take the simple problem of the kettle. I have listed 21 requirements which must take values within specified limits in an acceptably designed kettle. Given a set of n things, there are 2^n different subsets of these things. This means that there are 2^{21} distinct subsets of variables any one of which may possibly be an important component subsystem of the kettle problem. To name each of these components alone we should already need more than a million different words — more than there are in the English language.

A designer may object that his thinking is never as verbal as I have implied, and that, instead of using verbal concepts, he prepares himself for a complicated problem by making diagrams of its various aspects. This is true. Let us remember, however, just what things a designer tries to diagram. Physical concepts like "neighborhood" or "circulation pattern" have no more universal validity than verbal concepts. They are still bound by the conceptual habits of the draftsman. A typical sequence of diagrams which precede an architectural problem will include a circulation diagram, a diagram of acoustics, a diagram of the load-bearing structure, a diagram of sun and wind perhaps, a diagram of the social neighborhoods. I maintain that these diagrams are used only because the principles which define them — acoustics, circulation, weather, neighborhood — happen to be part of current architectural usage, not because they bear a well-understood fundamental relation to any particular problem being investigated.[19]

As it stands, the selfconscious design procedure provides no structural correspondence between the problem and the means devised for solving it. The complexity of the problem is never fully disentangled, and the forms produced not only fail to meet their specifications as fully as they should, but also lack the formal clarity which they would have if the organization of the problem they are fitted to were better understood.

It is perhaps worth adding, as a footnote, a slightly different angle on the same difficulty. The arbitrariness of the existing verbal concepts is not their only disadvantage, for once they are invented, verbal concepts have a further ill-effect on us. We lose the ability to modify them. In the unselfconscious situation the action of culture on form is a very subtle business, made up of many minute concrete influences. But once these concrete influences are represented symbolically in verbal terms, and these symbolic representations or names subsumed under larger and still more abstract categories to make them amenable to thought, they begin seriously to impair our ability to see beyond them.[20]

Where a number of issues are being taken into account in a design decision, inevitably the ones which can be most clearly expressed carry the greatest weight, and are best reflected in the form. Other factors, important too but less well expressed, are not so well reflected. Caught in a net of language of our own invention, we overestimate the language's impartiality. Each concept, at the time of its invention no more than a concise way of grasping many issues, quickly becomes a precept. We take the step from description to criterion too easily, so that what is at first a useful tool becomes a bigoted preoccupation.

The Roman bias toward functionalism and engineering did not reach its peak until after Vitruvius had formulated the functionalist doctrine.[21] The Parthenon could only have been created during a time of preoccupation with aesthetic problems, after the earlier Greek invention of the concept "beauty." England's nineteenth century low-cost slums were conceived only after monetary values had explicitly been given great importance through the concept "economics," invented not long before.[22]

In this fashion the selfconscious individual's grasp of problems is constantly misled. His concepts and categories, besides being arbitrary and unsuitable, are self-perpetuating. Under the influence of concepts, he not only does things from a biased point of view, but sees them biasedly as well. The concepts control his perception of fit and misfit — until in the end he sees nothing but deviations from his conceptual dogmas, and loses not only the urge but even the mental opportunity to frame his problems more appropriately.