onds altogether — roughly one minute to complete the adaptation.[8]

The step-by-step approach works. The all-or-nothing approach does not work. This is the secret of biological evolution. During the course of evolution, the adaptation of the thousands and millions of variables that must occur to make one successful organism happens step by step, essentially one gene at a time. That is what makes evolution possible. It would be impossible for nature to "design" a system as complex as an organism all at once.[9]

The same *must* happen when a building is designed and built, if it is to be well adapted and to have living structure. A building has too many aspects, too many variables. We cannot get each aspect of the building right unless it is possible to work out one aspect at a time. This is how we get the system of thirty coins to be all heads, except that in a building it it must be possible to do this for *thousands* of variables, one after the other, both during design and construction.

We may infer, then, that to make things come out right in the built environment, to bring adaptation into society and to regain our capacity to make buildings and streets *just right* — there is a simple condition that must be met. *The process must go gradually, in a way that allows assessments, corrections, and improvements to be made about the degree of life which occurs throughout the structure, at all scales and at all levels. This process must occur continually throughout conception, design, and construction*. And the process must be sufficiently widespread to affect all scales of building and construction.

5 / FEEDBACK

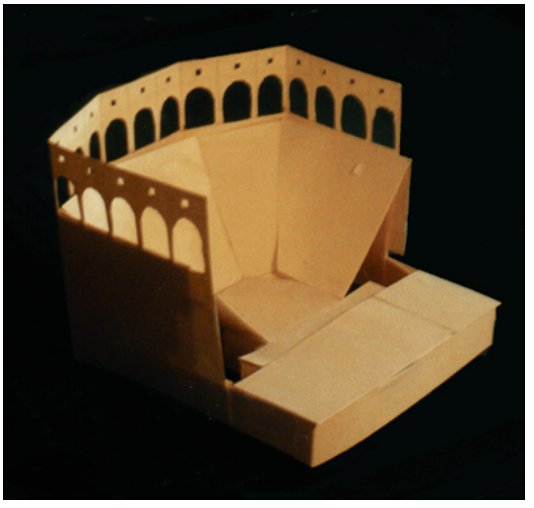
Of course, it is not enough merely to go step by step. As part of the step-by-step adaptation, there must also be a *feedback* process.

In traditional society, while a thing was being made, it was also *continually* being assessed for its degree of life — checked, corrected, improved, checked, corrected. This assessment was driven by some criterion of how much life the thing had — in some form, anyway — and the process was effective in allowing this criterion of life to guide the thing. Naturally, the thing, whatever it was, then gradually became alive.

However, in modern society — especially in those cases I have illustrated in chapter 4 that are plainly negative — neither the design process nor the construction process provide opportunity for gradual step-by-step feedback to influence the whole. Whether or not degree of life is noticed as an attribute while the building is being conceived, drawn, and built, this perception has little opportunity to influence the whole. *Feedback is not allowed to be effective.*

So, to work well, a living process must not merely be step by step. It must be step by step *with* a built-in feedback of such a kind that each step taken can be checked at once for the increase of life which will occur, accepted if it has it, rejected if it does not.

It sounds obvious. But it is not what happens in the processes of architectural design and construction that contemporary architects typically follow. During design, typically, we start with a schematic drawing. This drawing, being complex, usually contains hundreds (if not thousands) of decisions. Yet these decisions, if we separate them from one another, have been made on paper without one of them being tested.[10] Of course, at some stage the drawing is shown to the client, and the client has the right to comment on a completed whole. But by that time, the drawing, in its outline, is all but set, containing hundreds of untested decisions. Often not one of the hundred steps which led to its creation has been tested, nor have we, the architects, had



Small paper model of an intimate auditorium for the Mountain View Civic Center: the first step in finding a good form

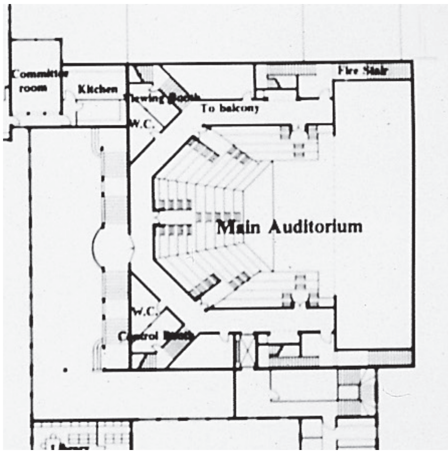
available to us a contemporary method of designing which can give us real feedback, step by step, as we work it out.

For illustration, consider the design of a large concert hall. How could this be done step by step? The usual way we undertake such a task is to conceive ideas for a possible design, begin to make drawings, develop the idea, work out the periphery of the building, work out the structure, the cost, and so forth. At later stages, acoustic engineers and lighting consultants come in. In this usual process, there is little or no *true* feedback throughout this long sequence of events. There are comments from the client, from others in the office, and so forth. But little *true* feedback about *the actual behavior* of the proposed building. Surprisingly, given the complex nature of the three-dimensional configuration of a large auditorium, there has, during the normally accepted design process, usually been little or no empirical feedback of a realistic sort about whether the concert hall works. Is it comfortable? Is it pleasant? Can one see? Is the feeling of the hall profound? Is the light good? Is the atmosphere what is wanted? These things have been discussed with the client, no doubt. But have they been *tested empirically* to see if the current configuration, as designed, actually has these functional features that are wanted and believed in by the designer?

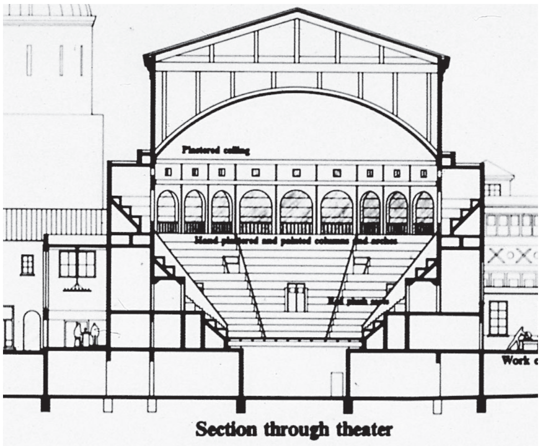
In order to make such a design process go step by step with feedback, the following thing would have to happen: *continuously, while making the design*, we would have to model the hall in a three-dimensional form sufficiently close to a person's real experience of the finished hall, so that this model would enable us to make realistic judgments about atmosphere, feeling, acoustics, etc., and would help us to make *improvements in the three-dimensional form* as we go along.

The crux of the difficulty is to find a medium in which we can make sufficiently subtle three-dimensional simulations. The core of architecture lies in the complexity of the three-dimensional configurations which are created, and in the difficulty of inventing them, unfolding them, visualizing them. The real site, in the real world, is a good place for simulations of building position, volume, and so on. But the complex interior configuration of a building — with spaces perhaps hundreds of feet across, perhaps several stories high, and complex in their feeling — how are we to achieve this, so that we can feel what is happening, and keep changing it, until it is really good?

Computer simulations cannot — at present — do these things at the necessary level of subtlety or depth. There are some kinds of computer simulation that provide real feedback about the behavior of a building after it is drawn. One example is the use of finite element analysis for structural design, described in Book 3.[11] There we draw a structural configuration and receive direct feedback from the computer about its structural behavior, allowing us immediately to improve the configuration again and again, until it reaches a stable and harmonious form. This works. The locomotive example on page 152 is similar: the wind tunnel test is not happening in a real wind tunnel, but in a computer simulation of a wind tunnel. The simulation gives immediate feedback about the shape of the locomotive nose, thus allowing the nose to be changed, then retested, until a good shape emerges.



The small auditorium was worked out in the paper model on the left. By playing with the paper model we could find a beautiful and intimate and exciting configuration which was intense and comfortable. Many experiments were made. We cut here, made the sides steeper, made the center smaller, made the arches around the perimeter — on and on — until it settled down to be a shape in which one could imagine feeling genuinely alive.



The plan and section drawn here came after — not before — the paper model on the left was made. After adjusting the model, getting sizes and angles right, putting in the arches, making the steepness of the auditorium slope just right, we could then finalize the design in early hardline drawings. The feedback from the model while making and developing the model is what made it possible to make it beautiful.

Cardboard and paper model used during design of another auditorium, the Eishin Great Hall, in Tokyo. The model allowed me to judge, then modify, the light and space as they would affect people inside.

Years later: a concert in progress in the finished Eishin Hall. Positive results of the early model work are visible, and further elaborations have also become part of the whole.

But the *effect* of a complex building space on the people in it is more complex; it is not, at present, quantifiable, nor is it reliably experienced by means of the three-dimensional images and supergraphics in computer simulations. As a result, no amount of computer simulation tells us what we want to know, which is, "How does it feel, what is its visceral effect on us?" In the absence of this kind of feedback, the building cannot be significantly improved because its *feeling* cannot be intensified. That is why the creation of a building design, by contemporary means, only very rarely succeeds in having a profound effect on us.

There are practical solutions to this problem. One approach that helps is the use of a long series of simple, cheap, quick, paper and cardboard models which can be tested, modified, tested, modified, rapidly, one after the other, so that a good solution has a chance to evolve. Very simple, intentionally rough paper and cardboard models do work. You tear, cut, tape, patch, and paste as you go, making the model better all the time. You can only do this if you have a model so crude that you don't mind cutting into it, and so roughly made that tape, scraps, bits, and pieces do not distract from the effect of the whole.[12] In today's practice, such models are rarely used for design purposes. Models *are* very often used for *presentation*, but that is quite another matter, one that does not contribute to design or feedback.

6 / THE RESULT MUST BE UNPREDICTABLE

To make the feedback meaningful in a step-by-step process, the process must be open-ended, hence partly unpredictable. It must *lack* a fixed, predetermined end-state. This is necessary because adaptation itself means nothing if changes cannot be made in response to the process of adaptation. By definition, such changes cannot be foreseen.

In traditional society, the evolving building was always in some degree allowed to go where it wished to go, or where it needed to go. Traditional society allowed its objects and buildings to be unpredictable in their details, and therefore genuinely allowed them to unfold. But in the more typical, more heavily mechanical production of our modern society — and especially in the structure-destroying cases I have referred to — the end-product is fixed too early and too rigidly. For a variety of reasons — legal, financial, and procedural — under modern conditions the thing is fixed too exactly, too far ahead, and has far too little freedom to unfold. Because of social and legal norms introduced in the second half of the 20th century, the end-product was more and more often required to be exactly like the blueprints — the plan, the master plan, the drawings, or the design — and no longer allowed to deviate from them. It thereby shut off, nearly altogether, the possibility that useful testing or adaptation could occur. But when adaptation and feedback are working, the result *must* be unpredictable. There must be tacit recognition that the end-result is not yet known.

This means not only that the end-result of a building project must be unpredictable during design. That is obvious. But to be effective in creating living structure, it cannot help also being unpredictable during *construction*.

Consider the windows in a house. In order to make rooms wholesome, the windows must create good light in the rooms, and must also create a good connection with near and distant views. But what is a "good" connection? It depends on important minutiae of the real situation. If a house is being framed, and I stand in one of the emerging rooms, I will see exactly where the actual landscape outside makes me inclined to look. But the precise way that the land-