and compared. But after hard work at each step it became possible to find out which of the alternatives that could be imagined preserved the wholeness most.

It is perhaps important to emphasize the novelty of the trusses which emerged from this process. In Book 2, I have stated that the fundamental process will produce a unique thing each time that it is used. This may be seen dramatically in the present case. Trusses had never before been built by this technique: They were shot with gunite, in the air. But what is more interesting is that this truss was completely new *as a structural configuration* — hence as a piece of engineering. A two-dimensional truss in which the tension, compression and bending are distributed in the bootstrap basket fashion we reached in this truss, was a completely new idea. It did not emerge from the intention or desire for a new idea. It followed just from the fact that the latent centers which existed in the wholeness of this emerging truss design were continuously respected and developed, step by step, while we watched what happened. Thus, what sounds like a conservative, dull process actually led to startling innovations.

The floral plant-like truss which came from this process followed naturally from the unfolding process. Yet it had never been seen before. Of course, two different individuals or groups, faced with the same problem, and taking the same steps, will not get the same result. Even if they find their way to one of the best half-dozen structure-preserving steps at each stage in the process, they will not choose the same ones, and the evolving designs will certainly diverge, in some cases dramatically, after only a few steps. So, of course, different engineers and architects will rarely go in the same direction. As a result, we get unique and beautiful works.

In our case the truss, its concrete, its shape, has a raw, gray, massive energy.

11 / APPROPRIATE STRUCTURAL ORDER FOR A LARGE APARTMENT BUILDING

We are committed to making each place, each room, window, floor, unique within the whole, according to its needs. How is this to be done in a large building?

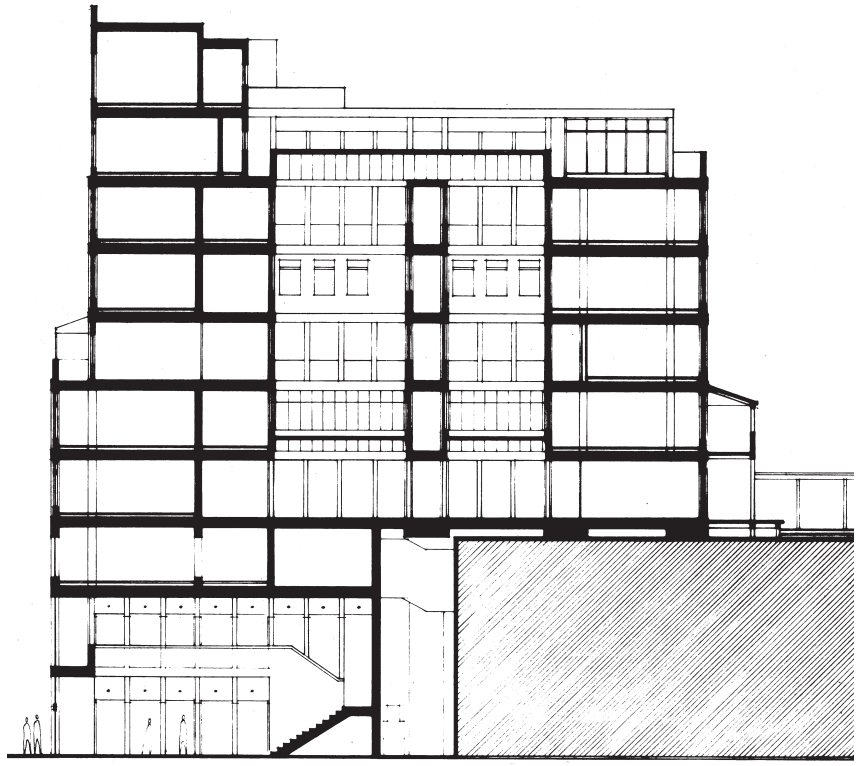
Nearly all very large buildings are built with the assumption that each floor is structurally identical, and that the upper floors mirror, exactly, lower floors. Plan variation is usually achieved by arranging lightweight non-bearing partitions within the uniform structural grid.

In most 20th-century buildings such perfect floor-to-floor repetition was a fundamental feature of the design, and without this feature most 20th-century large building designs would not work structurally. In addition, the repetition lowers the cost of contract administration. But most important is the fact that it creates a workable structural design. The columns, beams and shear walls have vertical continuity thus making a well-behaved structure.

But exact repetition does fly in the face of the fundamental principle of unfolding. It requires that each part of a structure become that which is unique and appropriate to its position in the unfolding whole.

If we look for a new kind of large building, in which there is greater freedom from such floor-by-floor constraints, we are then virtually looking for a new order-type, a new kind of structural design which will permit each part of the building to fulfill its own nature, have its own appropriate character, without placing impossible demands on the structural design.

My colleagues and I worked out an example



Sapporo ten-story apartment building, longitudinal section. Christopher Alexander and Ingrid King, 1984

of such a larger-scale sophisticated order type, in the case of the Sapporo building: a 10-story apartment building for the northern island of Japan. In this design the load is carried by a system of 13 structural column-groups, each one itself a cage composed of four smaller columns.

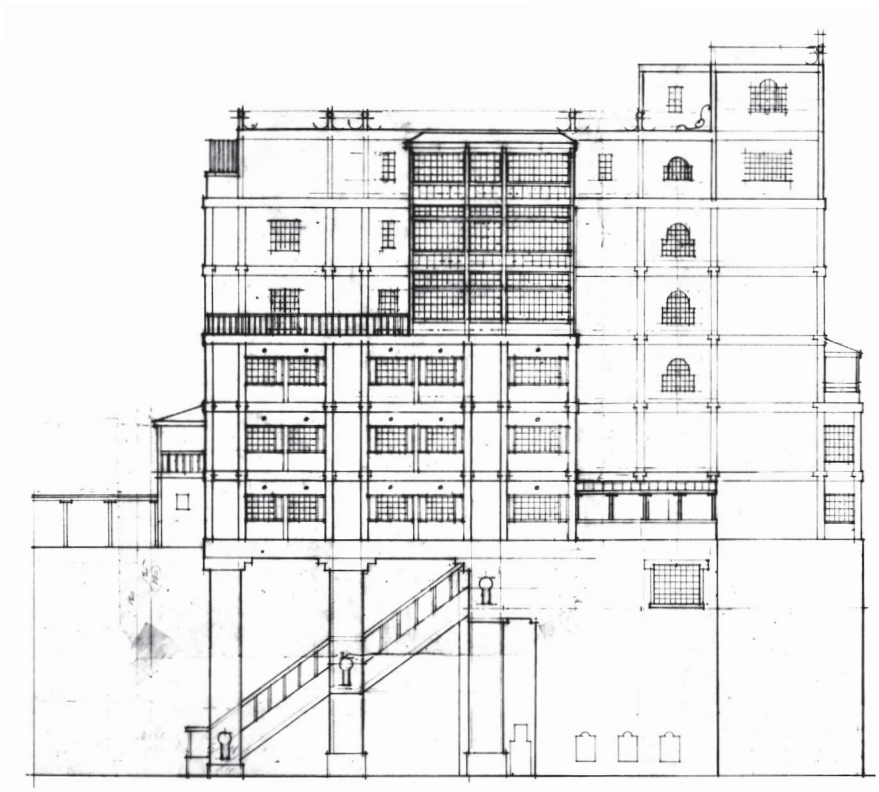
All the major features of this innovative structural scheme arose from the careful unfolding of the design with respect to user requirements, the impact of surrounding buildings, coupled with the peculiar fact that there was an untouchable small clinic on the site which had to be kept intact and therefore straddled, created a series of conditions requiring ten different plans at each of the ten floors.

For example, spanning over the clinic required massive legs to support the back of the building, and a smaller plan dimension for the first three floors. The users required two floors of shops and offices in front. Attention paid to the users' needs suggested a strong need to build gardens or balconies at different floors, thus creating a modest (but not absurd) stepping back and releasing balconies at the 9th and 10th floors, together with a roof terrace on the 4th floor.

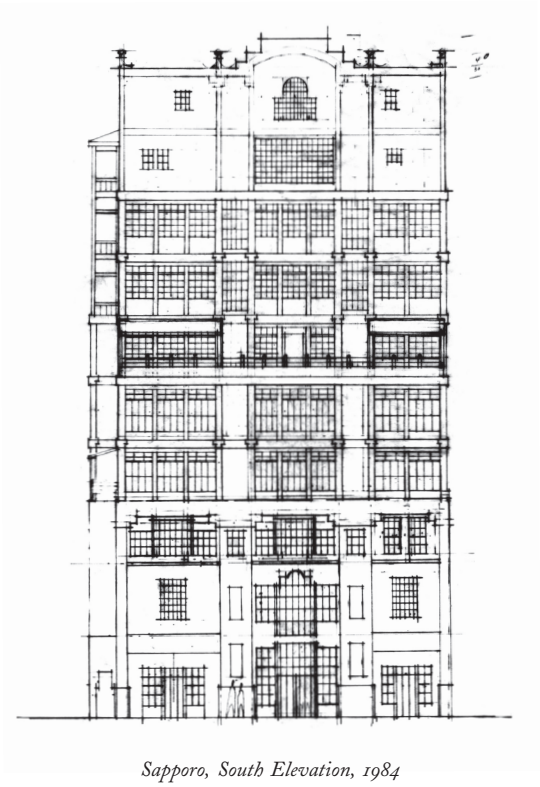
The demands of the street imposed a rather regular rectangular facade: with some stepping back towards the upper floors, for light and air, generated by the planning code for Sapporo.

There were also some difficulties of internal circulation, created in passing from the 4th to the 5th floor, and the access to the roof terrace at the back of the building, thus further modifying successive floors inside the building. The need for interior daylight, further imposed by size and lack of light from the perimeter, suggested construction of a central light well in the upper floors, doubling as a major source of movement.

The progressive changes from floor to floor, the progression from ground to roof, and the variations — many of them inevitable, arising from the changes in plan — are visible in the ten



Sapporo, West Elevation, 1984

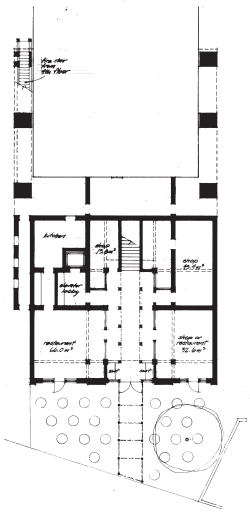


Sapporo, South Elevation, 1984

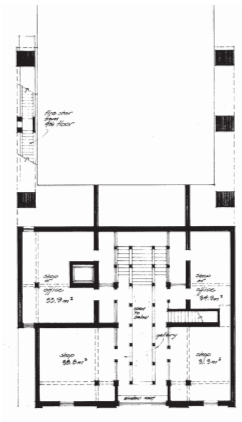
floor plans shown on these pages.

In order to make a good and coherent building, with these substantial floor-to-floor variations, we then had to invent a structure which would keep the structure coherent with the social spaces,[7] and could accommodate the variations, without sacrificing structural continuity of columns and shear planes. Yet for reasons that are explained more fully in Book 2, chapter 15, on pages 412–16, we decided from the outset that the structure must be a true coherent structure where the material of beams, columns and walls, coincide with the architectural and social space required for the apartments and passages and rooms.

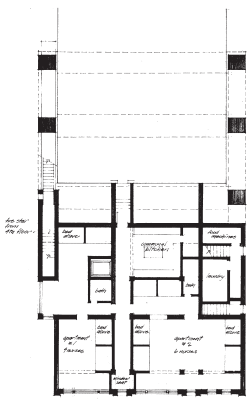
The aperiodic grid with large bays and small bays solved the problem. It came, originally, from the observation that each apartment would greatly benefit from the classic Japanese gallery, often found at the garden face of a traditional building. This kind of space, usually 3 feet (one tatami) or 4 feet wide, also coincided with the possibility of stairs and passages occurring within the grid.



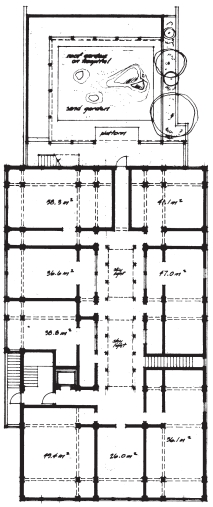
1st floor lobby and shops



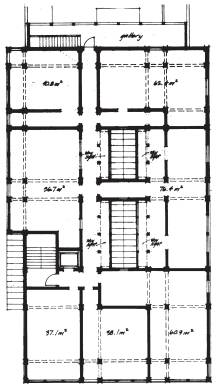
2nd floor lobby and shops



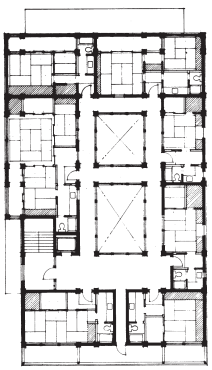
3rd floor apartments



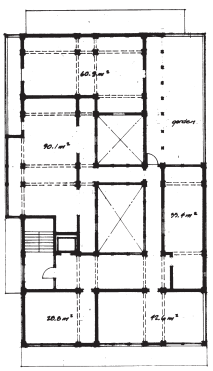
4th floor apartments



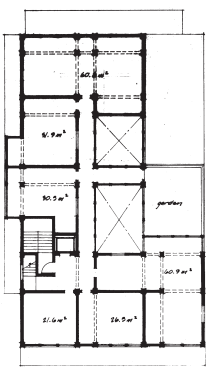
5th floor apartments



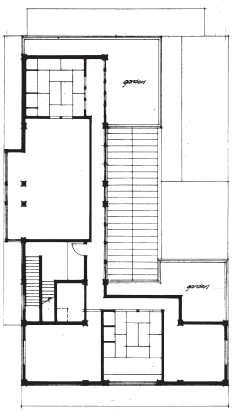
6th floor apartments



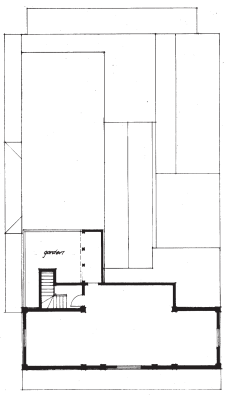
7th floor apartments



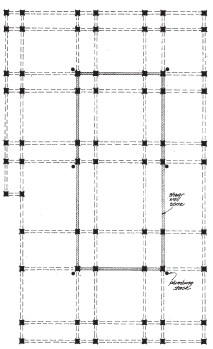
8th floor apartments



9th floor apartments



10th floor apartments



structural grid

If the reader examines each of the floor plans, with respect to the underlying structural grid, it may be seen how each floor fits the same grid, but in a different way at each floor.

This building, designed to work in bending as a moment-resisting frame, with supplementary action from shear walls at the lower floors, allowed the plans to change freely from floor to floor, and allowed us to a plan a 10-story building in which every one of the ten floors is different — yet all tied together, unified, and resolved structurally, by the continuity of the 13 clusters of 4 columns that pass through each plan in the same positions.

This example gives a hint of future structures in which similar syncopated structural arrays can make possible an underlying organic structural order in large buildings.

12 / MORPHOLOGICAL INVARIANTS THAT ARE LIKELY TO APPEAR IN AN ENGINEERING STRUCTURE GENERATED BY LIVING PROCESS

A building is an arrangement of several thousands of tons of concrete, stone, brick, steel and glass, with smaller amounts of other materials thrown in. The pattern of this solid matter, as it is distributed in space, is rarely mentioned. Yet it is this pattern of solid and void, in three dimensions, which governs everything of importance in a building, everything substantial.

When living processes guide the formation of a building structure, these are the features which will settle out. The relation of mass to space: Each is positive to the other: the spaces will be formed as good shapes by the material, and the material will be formed as good shapes by the space. The creation of the two interleaved patterns, one of matter, one of space, each coherent in its own right, the material coherent according to its structural laws, the space coherent according to human laws, when successful becomes a triumph of imagination, a kind of fugue in space.

Generally it does not work when the members are too thin, because that has a destructive effect on the space. So the centers of the material have to be made rather big and rather solid — and that usually means they must be far apart. Yet to form significant human space they have to be close together, to form the spaces themselves. The creation of a meaningful structure lies in the resolution of these opposites.

It is extraordinary how the pure pattern of space, substance, and volume, when conceived as a structure of centers in abstract geometric terms, without detailed analysis of forces, so naturally becomes a coherent engineering structure. The fundamental process, because of the geometric structure it induces, helps to create a beautiful and living engineering structure.