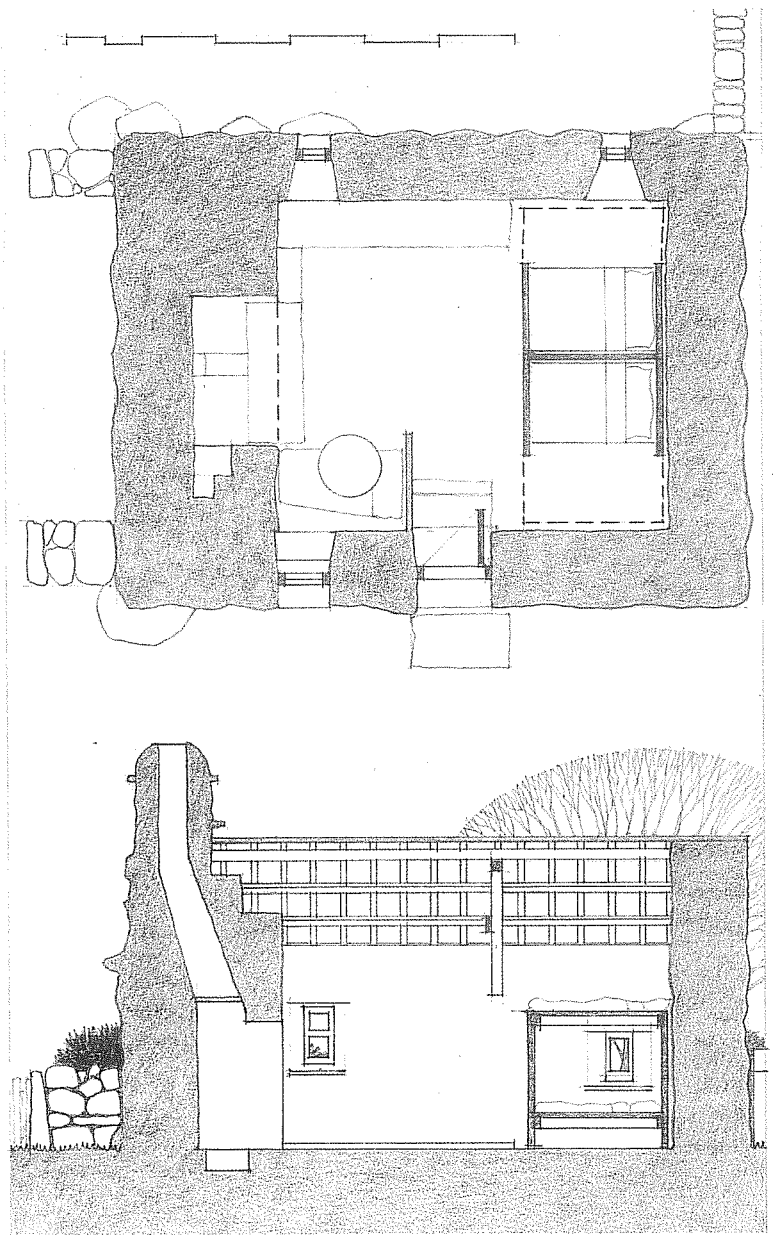


SPACE
AND STRUCTURE

SPACE AND STRUCTURE

Both structure and space are media of architecture. It is by reason of its structure that a building stands. Structure also plays a part in organising space into places. The relationship between space and structure is not always simple and straightforward; it is subject to different approaches.

In terms of attitudes, one can either choose and allow a structural strategy to define the places one wishes to create, or one can decide on the places and, in a way, force structure to cope with them.

There are thus three broad categories of the relationship between space and structure: the dominant structural order; the dominant spatial order; and the harmonic relationship between the two, in which spatial and structural order seem in agreement. In the history of architecture, there have been champions of all three relationships, as evident in the examples below.

There have also been protagonists for a fourth category of relationship, in which spatial organisation is said to be separated from structural, so that they may coexist, each obeying its own logic free of the constraints associated with the other.

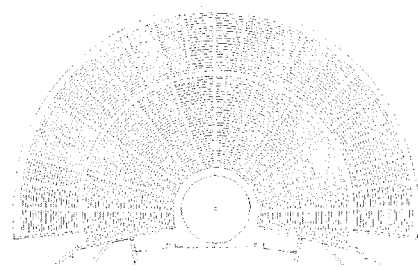
As we have seen in the chapter on *Geometry in Architecture*, regarding 'the geometry of making', structure tends to its own geometries. In the sections of that chapter regarding 'the geometry of being' and 'social geometry' we have seen that objects and people, individually and in groups, can evoke their own geometries. In architecture there are vital relationships between these geometries: sometimes they are in tension; sometimes they can be resolved into harmony; sometimes they can be overlaid but remain conceptually separate.

An extra complication is that once a structural strategy is established it can influence (not merely respond to) spatial organisation.

An important aspect of the art of architecture is to choose a structural strategy that will be in some sort of accord with the intended spatial organisation.

The way in which ancient Greek architects evolved indoor theatric places is a good illustration of how spatial organisation can conflict with structural, and how this can be resolved by compromises of different types, in both.

The classic Greek amphitheatre was a geometric formalisation of the social geometry of people sitting on the slopes of a hill watching a performance. Its three-dimensional form was a fusion of social geometry, ideal geometry, and the lie of the land. With no roof it did not have to take account of the geometry of structure.



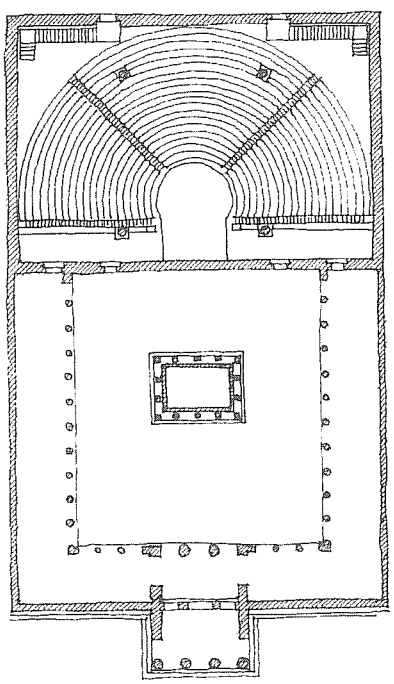
Opposite page:

In this cottage, called Llainfadyn, the purpose of the structure of the building is to organise a portion of space, identifying it as a place for dwelling. Structure and space are in 'symbiosis' – a mutually affective relationship.

In some cases however Greeks wished to create an inside place where lots of people could watch something. This meant having to take account of the geometry of the structure which would hold up the roof.

The structures which the Greeks used tended to create spaces which were rectangular in plan; and they could not achieve large spans. Both these characteristics conflicted with the shape of an amphitheatre, which was circular, and needed an uninterrupted large space.

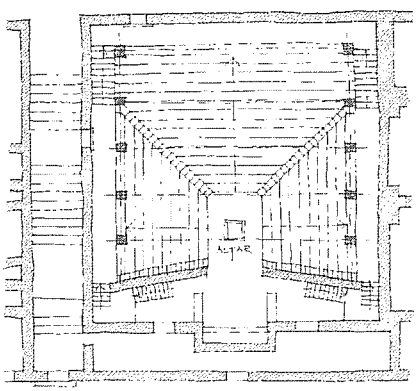
In some instances the Greeks' solution was merely to put the 'round peg' into the 'square hole'; this is the council chamber at Miletus.



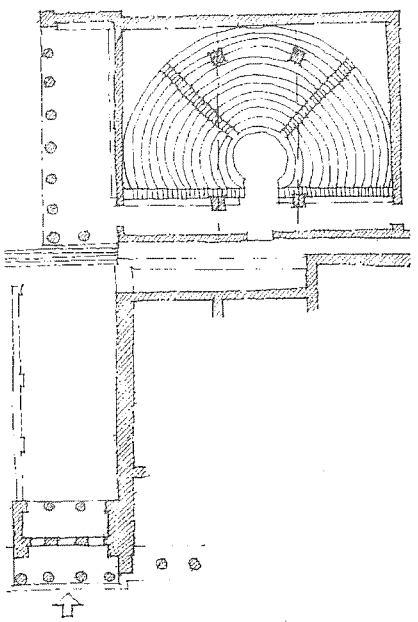
The amphitheatre is enclosed in a quadrilateral cell, leaving corner spaces unused except for stairs back down to ground level. The columns needed as intermediate supports for the roof have been kept to a minimum; the two at the front are to some extent used to help frame the focal space of the chamber, but the other two are awkwardly intrusive. A minor concession to the geometry of the seating is made in the way the column bases take their alignment from the seats rather than from the orthogonal geometry of the structure.

Almost exactly the same relationship between spatial and structural organisation, but on a smaller scale, is found in the 'new' (late fifth-century BC) council chamber built in Athens (right). Presumably the two pairs of columns, together with the external walls, supported principal structural beams along the lines shown in the plan, which then divided the long dimension of the roof into three smaller, manageable, spans.

In other examples the shape of the seating is made to fit the rectangular geometry determined by the structure. This is the *ecclesiasterion* at Priene.



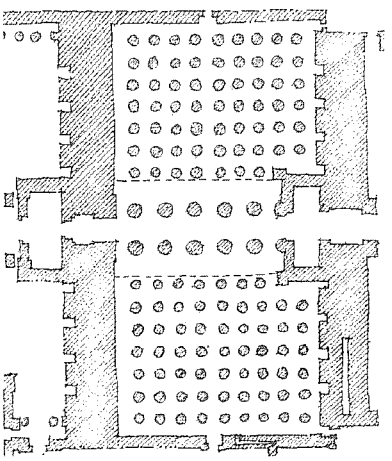
Here the seating has been mutated to the closest rectangular equivalent of the segmental amphitheatre. There is compromise in the structure too, in that the intermediate supports –



In the council chamber at Athens an amphitheatre of seating was enclosed within a rectangular cell. The columns needed to support the roof were kept to a minimum and carefully positioned to create the least obstruction to view.

the columns introduced into the space to reduce the spans of the roof timbers – are not positioned at the 'third points' where they would divide the width of the hall into three equal spans, but have been placed much nearer to the outside walls so that they do not obstruct views from the seats.

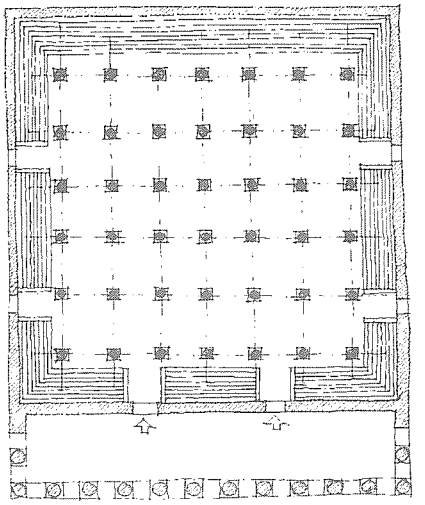
In early buildings that tried to create large roofed spaces columns were indispensable. This is an ancient Egyptian 'hypostyle' hall, from the temple of Ammon at Karnak dating



from the late fourteenth century BC. Whatever the space was used for, it would have had to contend with the forest of huge columns, the smaller of which had a diameter of more than three metres.

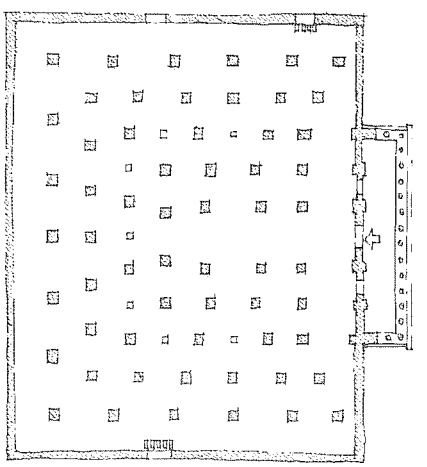
The ancient Egyptians may have just been impressed by a space filled with huge columns, but the same arrangement would be a problem in spaces for performance.

This is the case in the *telesterion* at Eleusis, built in the sixth century BC as a place for the performance of the secret 'Mysteries'. It has seats for spectators around the periphery of a square space. Over the performance area is a regular grid of columns to support the



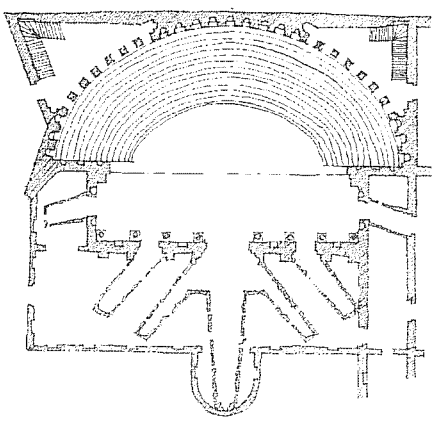
roof. These obstructed everyone's view of what was happening on the floor.

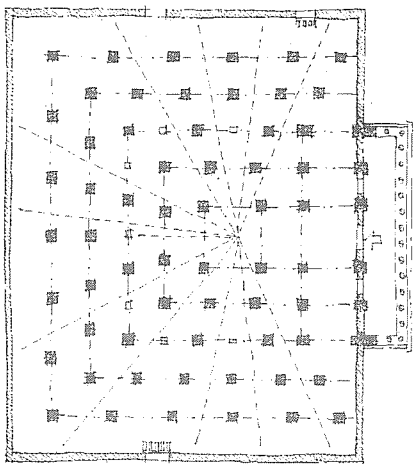
The next plan – of the *thersilion* at Megalopolis (fourth century BC) – appears to have a similar profusion of obstructive columns, except that at first sight they seem to be scattered irregularly across the floor.



If however one superimposes an interpretation of the grid of the roof structure, one can see that the columns were arranged with a particular spatial

The Renaissance architect Andrea Palladio, wishing to evoke the spirit of the ancient theatres, had to use ingenuity to contrive this oval amphitheatre inside the Teatro Olimpico (AD 1584). In the auditorium the mismatch between the curved seating and the outside walls is masked by an arcade of non-structural columns. The stage setting includes a sophisticated scene incorporating false perspectives.

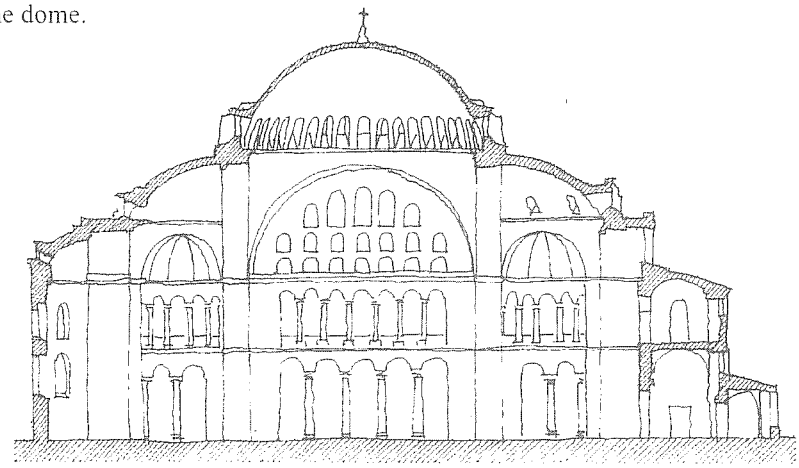


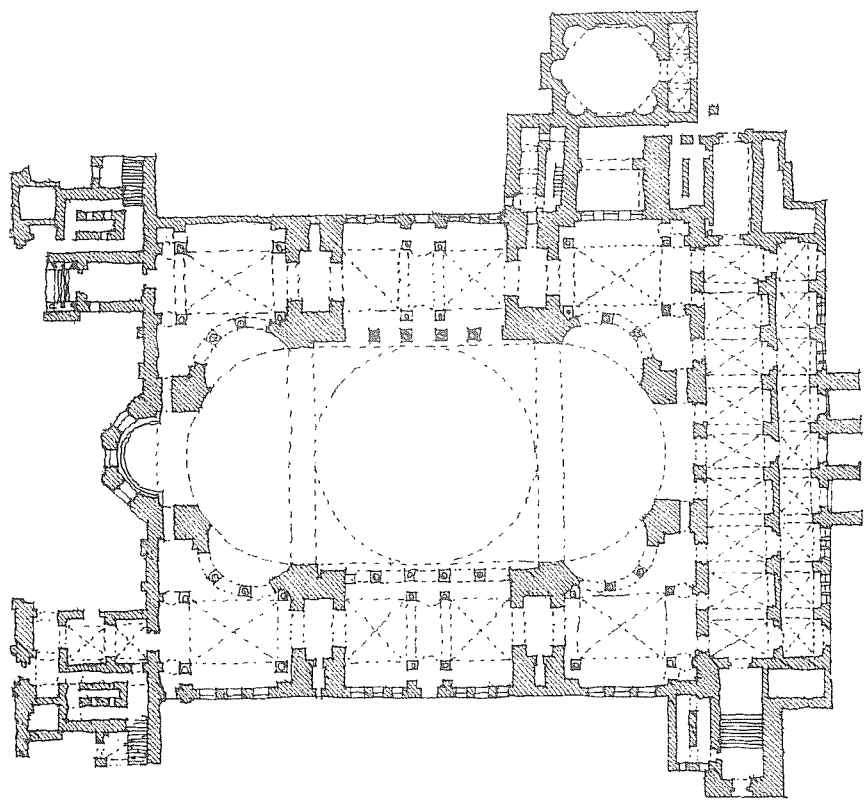


intent, one that responds to the lines of sight which radiate from a point of focus under the four columns which do make a square on plan. This appears to have identified the place where a speaker would stand; and the distortion of the grid of columns was a compromise in favour of a spatial arrangement that would allow him to be seen as well as heard.

Through history, many works of architecture have been created under the power of a conviction that structure is the fundamental form-giving force in architecture, and that the geometric order inherent in resolved structure is the most appropriate order for space too. This conviction is perhaps most apparent in the religious architecture of the Romanesque and Gothic periods, but it has been the impetus behind many nineteenth- and twentieth-century buildings too, both religious and secular.

In the Hagia Sophia in Istanbul, built as S. Sophia in the sixth century AD, the structure *is* the architecture: the spaces it contains are ordered by the pattern of the structure; the places within the building are identified by the structure; the sacred place itself is identified from the outside by the structure of the dome.

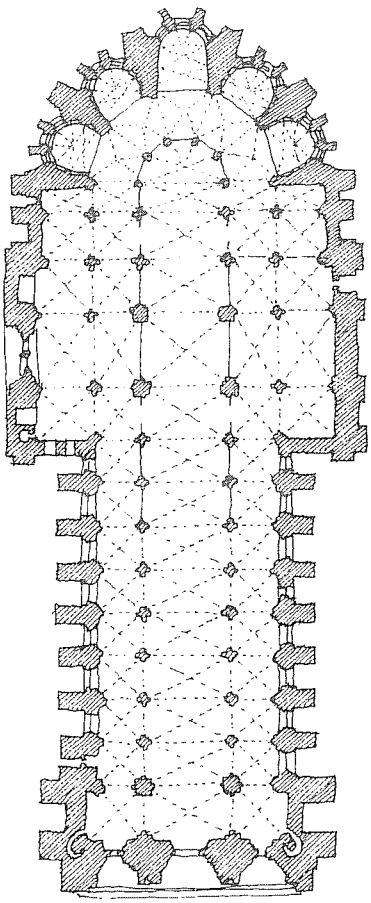




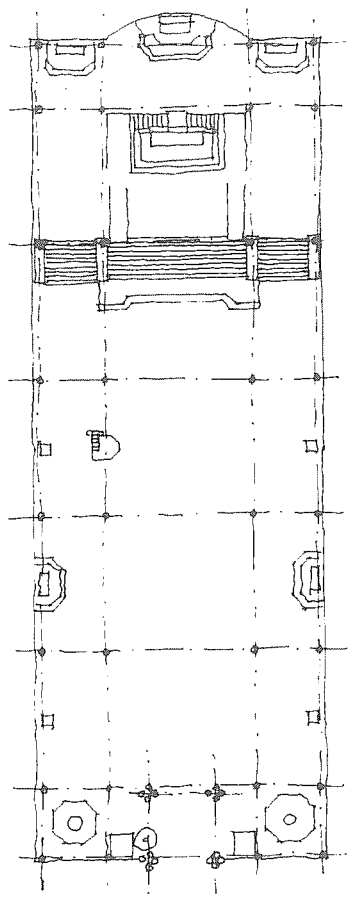
This intimate relationship between space and structure is illustrated in medieval churches and cathedrals too. Their places – the sanctuary, chapels, nave, etc., are all identified structurally, by resolved stone vaults.

The Hagia Sophia and the medieval cathedrals were built in stone, but the intimate relationship between structure and spatial organisation that they exhibit occurs in structures of other materials too.

The French architect and pioneer in the use of reinforced concrete, Auguste Perret, translated the structural and spatial clarity of the medieval churches into concrete structure. This



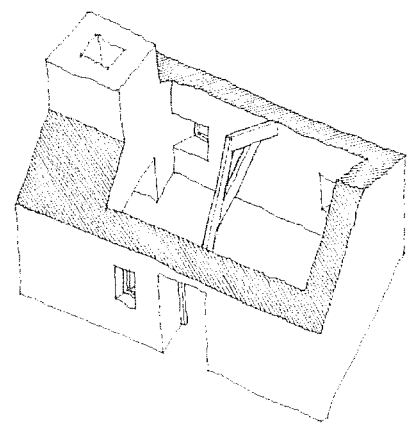
In Rheims cathedral space is ordered by structure.



is his church of Notre Dame at Le Raincy just outside Paris, which was built in 1922. It is a smaller building than Rheims cathedral, but even so the proportion of the floor area taken up by the structural supports is much less, because reinforced concrete is much stronger, structurally, than stone. The relative distance between the columns in Le Raincy is much greater than in Rheims for the same reason. The structural and spatial clarity in both churches is however the same. In Perret's church all the places are identified by the structure: the position of the main altar, the positions of the secondary altars, the pulpit, the font, and so on, are all determined by the spaces defined by the structure.

The space planning requirements of religious buildings are usually fairly simple: the places to be identified can be easily accommodated in the geometric order of structure which also seems to reinforce the spiritual order offered by religion. But in domestic architecture the relationship between structural order and spatial organisation can be more fraught.

The relationship between space and structure in a simple single cell house is straightforward: all the places to be accommodated happen under the



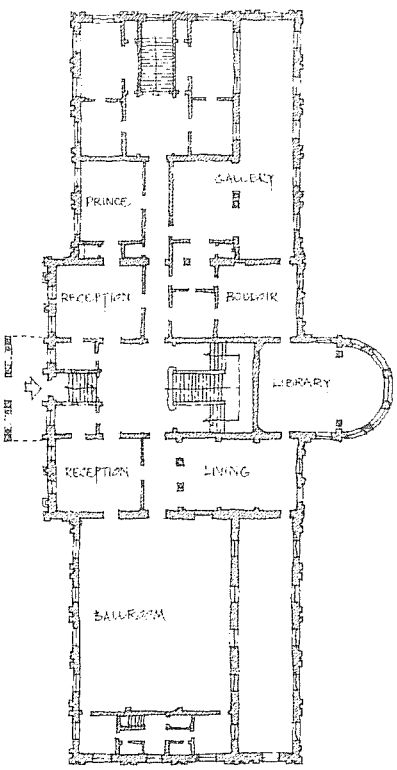
shelter of the roof and within the enclosure of the walls. There may be some principal roof timbers, like the simple truss in the example above, but

Reference for the work of Auguste Perret:

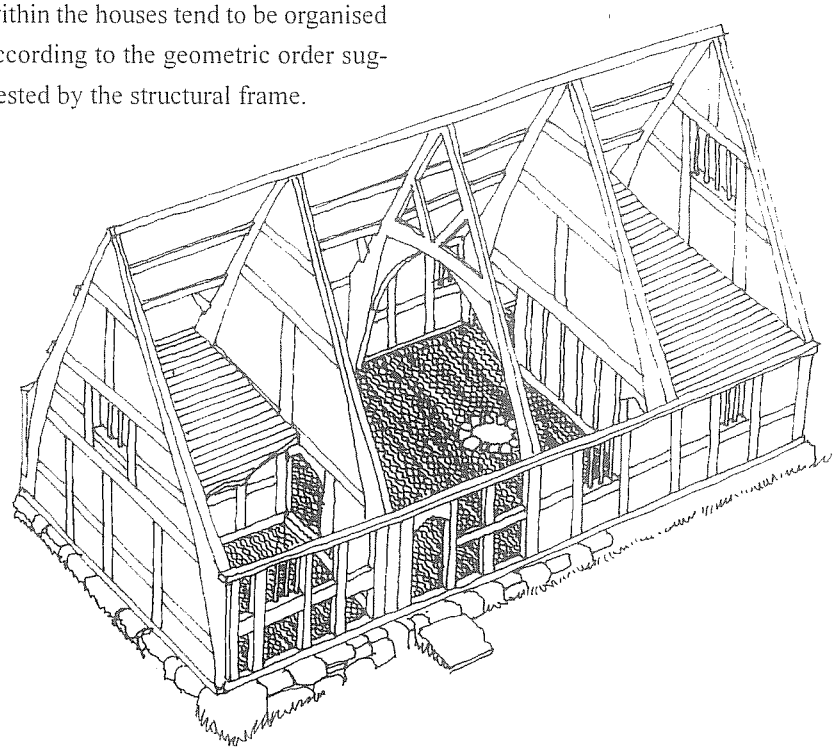
Peter Collins – *Concrete*, 1959.

this is unlikely to influence spatial organisation in the room below. This room is defined by walls which clearly and inseparably perform the dual functions of enclosure and structural support simultaneously.

At the other end of the scale of complexity, large houses built of loadbearing wall structures tend to have their spaces organised into many cellular rooms. Probably the heyday for this type of house was during the Victorian age when many people with newly acquired wealth had large houses built for them.



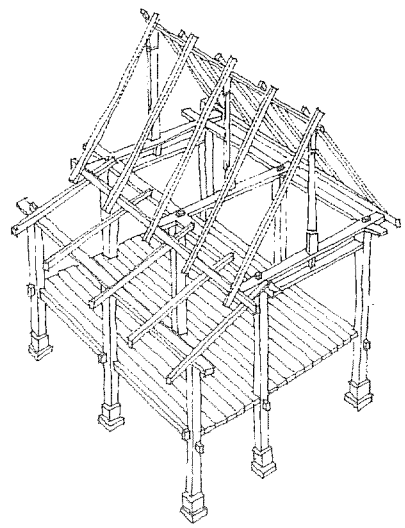
There are many types of traditional house in which the two functions of enclosure and structural support of the roof are distinguished from each other. In these the roof is supported on a frame of timber, and the spaces are enclosed by non-loadbearing screen walls. These framed buildings may be simple single cell houses, or they may consist of a number of rooms. In traditional examples the rooms or places within the houses tend to be organised according to the geometric order suggested by the structural frame.

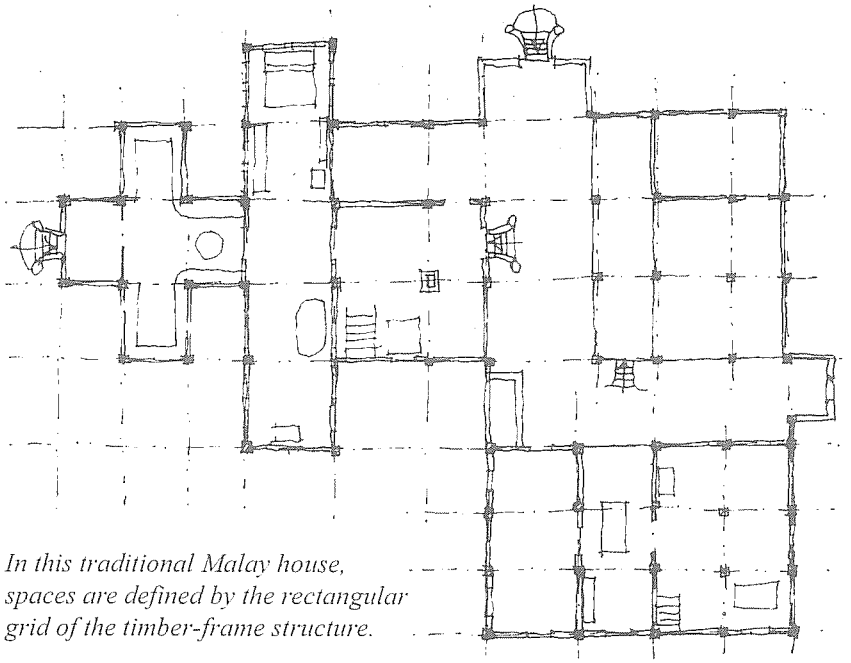


In this house there are small rooms on two storeys set in the two end structural bays, and a larger hall occupying the central two structural bays. The walls are filled in with light wattle and daub panels.

The plan of this house is a rectangle, but timber-frame structures can also have more complex plans.

Traditional Malay houses are built using a simple timber-frame structure. By processes of addition, they can become quite extensive, and composed of many spaces. The places they accommodate tend to be defined by the structural bays, which are sometimes accompanied by changes in levels.





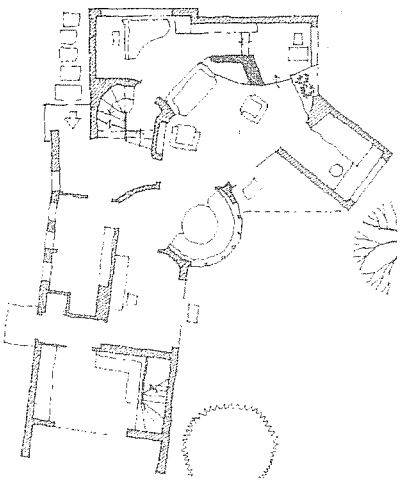
In this traditional Malay house, spaces are defined by the rectangular grid of the timber-frame structure.

Reference for Malay houses:
Lim Jee Yuan – *The Malay House*, (Malaysia) 1987.

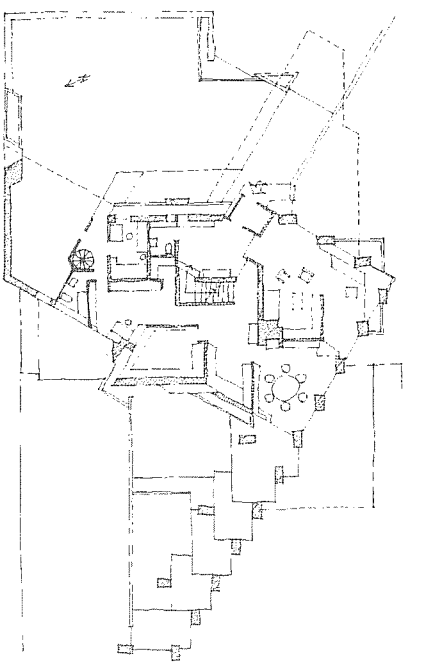
In the examples given so far, the geometry of structure has suggested that space be organised into rectangles. As we have seen in the section on 'the geometry of making', structure can tend to make circles as well as rectangles. Some houses of all ages have their space organised according to the circular order of a conical roof structure.

Some architects, particularly in the twentieth century, have argued, through their designs for houses, that the spaces associated with life are not necessarily rectangular or circular, and that dwelling places should not be forced into the geometric plan forms suggested by resolved structures.

During the 1930s in Germany, Hans Scharoun designed a number of private houses in which the disposition of places took precedence over the geometric order of structure. Here again is the Mohrmann house, which stands in a southern suburb of Berlin. There are places: for sitting by the fire looking out through a glazed wall into the garden; for playing the piano; for eating; for growing decorative plants.... The disposition of these takes priority over the structural organisation of the house.



This house too has a complex plan. It is the Casa Romanelli, designed by the Italian architect Angelo

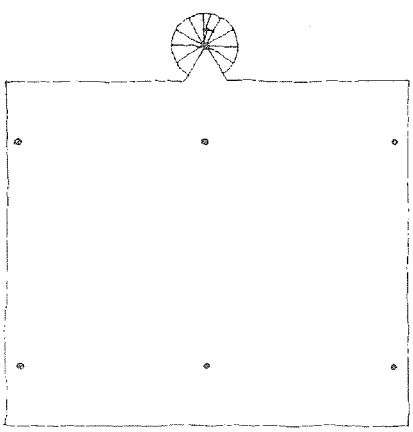


Reference for Casa Romanelli:
Architectural Review, August 1983, p.64.

Masieri and executed by Carlo Scarpa in the north Italian town of Udine in 1955. Though, as in the Scharoun plan, the geometry of this house is complex, its spatial organisation is more a result of the overlay of different geometries to create complexity. The disposition of places does not direct the design, but rather accommodation is found for them amongst the walls and columns. Though the structural pattern is complex, it leads and spatial organisation follows.

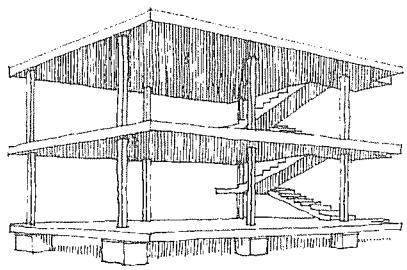
Some architects have tried to separate structural order from spatial organisation and place making.

There is a small house on Long Island, New York, designed by the architects Kocher and Frey and built in 1935. All its accommodation is on the first floor, which stands some two-and-a-half metres above the ground on six columns, and is reached by a spiral stair; on top is a roof terrace. This is a plan of the structural layout of the main living floor. Although the living place



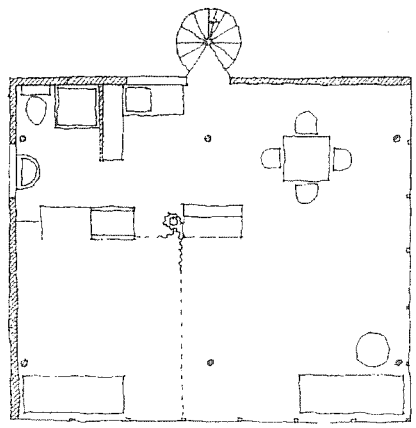
is defined by the extent of the platform, the structure of six columns positioned regularly across the plan makes no suggestion of how the floor should be laid out to make places. The drawing alongside shows how it was laid out; the walls are not load bearing. The movable screens which give the bed space some privacy are wrapped around, not another column, but the water downpipe.

This Kocher and Frey house is an example which follows the principle set by Le Corbusier some twenty years earlier in the 'Dom-Ino' idea. He

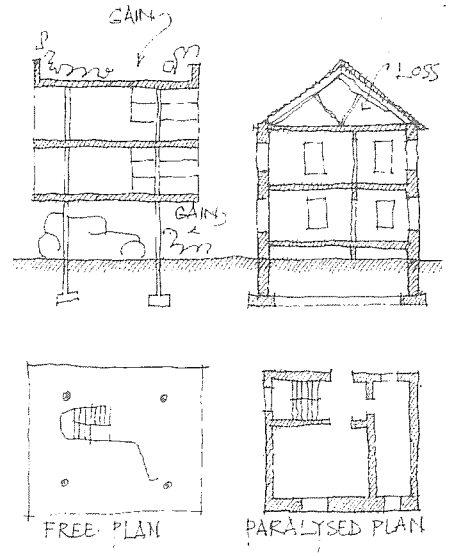


suggested that the planning of buildings could be freed of the restrictions of structural geometry by the use of columns supporting horizontal platforms.

Le Corbusier designed a number of houses using the Dom-Ino idea. Mies van der Rohe also experimented with detaching spatial organisation

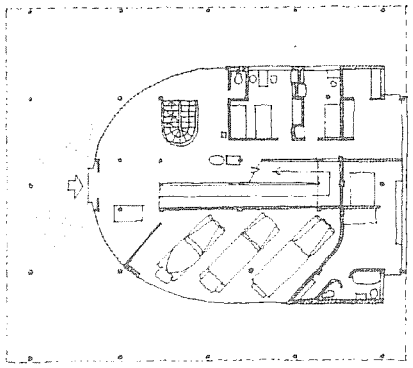


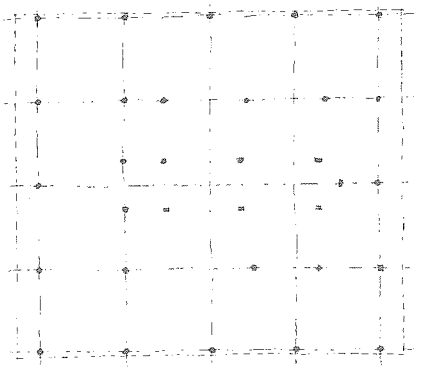
from structural order. Both however tended to allow structure a part in place identification. Both experimented with space between horizontal planes.



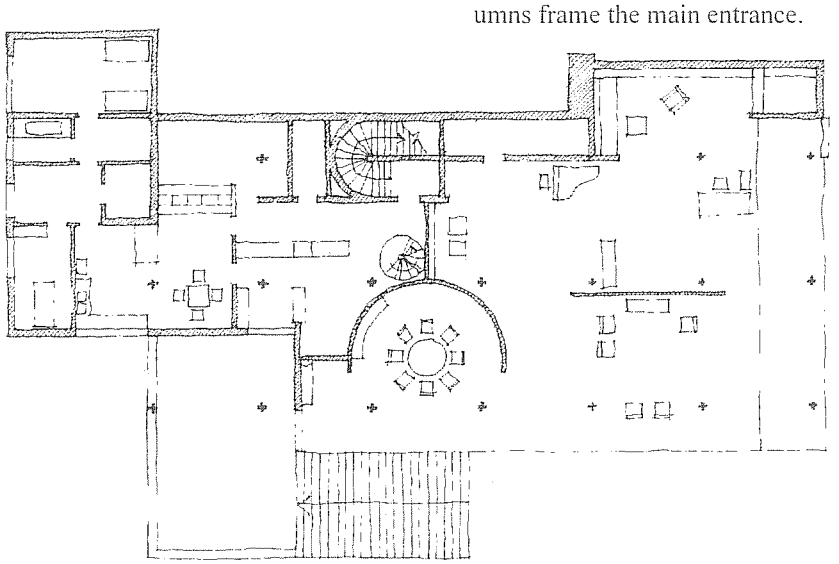
This is one of Le Corbusier's diagrams arguing the benefits of the Dom-Ino idea in the architecture of house design.

Reference for house on Long Island:
F.R.S. Yorke – *The Modern House*, (6th edition) 1948, p.218.





This is the structural diagram of the Villa Savoye at Poissy, near Paris, built in 1929. Clearly, as in the *thersilion* at Megalopolis, the structural grid has been distorted. Although the structure does not determine places within the plan, Le Corbusier does use it to help in the identification of places, as one can see, for example, in the drawing alongside: where the columns define the space occupied by the central ramp; where a column picks up the corner of the stair; and where two columns frame the main entrance.



In the Tugendhat House at Brno, (1931), Mies van der Rohe preserved the geometric order of the structural grid of cruciform columns, but he too used the columns to help identify places: two of the columns, together with the curved screen wall, frame the dining area; two others help define the living area; and another column suggests the boundary of the study area, at the top right on the plan.

In the Barcelona Pavilion (1929), however, in which Mies van der Rohe was almost totally free of the need to identify places for particular purposes, he managed to create a building in which space is liberated, almost completely, from the discipline of structure, and channelled only by solid, translucent and transparent walls.