#### CHAPTER ONE

# FIVE FORMAL PROPERTIES OF A COMPOSITION



RCHITECTURAL DESIGN IS ESSENTIALLY PATTERN MAKING. THE composition of a building is a set of patterns of various complexities organized one within another, like nested Russian wooden dolls. Ideally, every aspect of a building—from the plan in its most abstract sense to the smallest physical detail—appears in a pattern, and all of the patterns relate to one another dimensionally to create a seamless continuum of scale and complexity. This is what we observe in the organic compositions of the natural world—compositions that have five related formal properties: **number, geometry, proportion, hierarchy,** and **orientation**. They produce patterns at all scales of the natural world, from the scale of the cosmos to that of the atom.

**Number** is the fundamental property. The two dominant theories of the physical world—general relativity at the macro scale and quantum mechanics at the scale of subatomic particles—both rely on a mathematical language, that is, they assume that all physical phenomena are in essence numerical. Between these extremes of scale, nature is composed of numerical structures. Some structures are relatively easy to discern whereas others, such as the chaotic structures of weather systems, are extremely complex. Likewise, any analysis of formal order in architectural composition must begin with numerical relationships. Common features of space and time as we ordinarily experience them in architecture, such as rhythm and cadence, are numerical progressions.

**Geometry** is the shape of number. Like numbers, geometries in nature vary widely in complexity. Geometry is an underlying ordering mechanism that establishes a consistent language of form for a given phenomenon. For example, a crystalline pattern may assume a hexagonal geometry (based on the number six), whereas many plant forms depend on a pentagonal geometry (based on the number five). Each geometric figure has intrinsic qualities. The square, for example, is defined by its four equal sides and right angles. In architectural design, the relation of geometric figures is a visual language that is central to our reading of pattern. In many of the plans of Frank Lloyd Wright's houses, for example, spaces vary in size and other attributes, but they are geometrically consistent. Though their relations are complex, their geometrical similarity is critical to producing a sense of unity and continuity.

**Proportion** is the ratio of numbers within a geometric figure or among parts of a larger composition. For example, triangles of varying proportion are constructed from three points on a plane. The ratios of the distances between the vertices may be equal, producing an equilateral triangle, or they may have some other ratio, such as the series 3:4:5. Proportion also establishes the relative sizes and positions of the parts of a composition and is therefore essential to their functional relationships. It operates in the natural world, within some parameters of variation, as a means to produce consistency. For example, the human face has a proportional organization such that its features appear more or less in predictable places in relation to one another; extremely subtle variations in proportion also governs scale in architecture. Externally, it relates a building to the scale of its physical setting (landscape or other buildings) and to the scale of people. Internally, proportion controls the relative sizes of the parts of the architectural composition.

**Hierarchy** indicates the relative importance of the parts of a composition and is dependent on number, geometry, and proportion, since each of these contributes to the identity of each part and its position relative to others. Nature avoids uniformity because forms in nature respond directly to the distribution and collection of energy. Since sources of energy are concentrated or intermittent, not uniform, forms must organize themselves hierarchically to produce structures that mediate between places of high concentrations of energy and those of low concentrations. Analogously, in architectural patterns, not all parts are of the same significance. We can consider them in respect to energy as well—literally in respect to natural light, but also figuratively in respect to their visual, emotional, or spiritual energy.

**Orientation** operates in two ways in patterns: externally and internally. All natural phenomena are oriented in space in some way, in response to forces around them, such as sunlight or a magnetic field. They may be oriented externally toward patterns outside themselves, such as the sun or a direction of movement. They are also oriented internally by virtue of an organization of their parts (e.g., the axis of symmetry that controls the position of the head, thorax, and abdomen of a beetle and indicates its direction of movement). Likewise, in architectural design, we find buildings oriented externally toward distant objects, such as the Kaaba in Mecca for mosques or the polestar for some Anasazi kivas. Internally, orientation may take the form of an axis of symmetry, but there also may be a series of changing orientations in a choreographed movement though linked segments of space.

### A Maple Leaf

A maple leaf is a simple example of how these five formal properties produce a pattern in nature. It is composed of five lobes, three large and two small (1.1). Geometrically, the lobes are within a 180° arc in four 45° sections (1.2). Proportionally, the leaf fits within a rectangle that inscribes an equilateral triangle, a rectangle therefore with the proportion of  $2:\sqrt{3}$  (1.3). Since the function of the leaf's structure is to collect and distribute energy, it is hierarchical by means of primary, secondary, and tertiary veins (1.4). Finally, its orientation is symmetrical about a vertical centerline rising from a horizontal baseline (1.5). What is most fascinating about this rigorous system is that among the countless maple leaves nature has produced, no two leaves are ever exactly alike. The underlying rules of a maple leaf pattern (number, geometry, proportion, hierarchy, and orientation) ensure consistency without uniformity.



#### 1.1

Number: three major and two minor lobes.

#### 1.2

Geometry: division by 45°.

## 1.3 Proportion: the $2:\sqrt{3}$ rectangle.

#### 1.4

Hierarchy: primary, secondary, and tertiary veins.

### 1.5 Orientation: horizontal and vertical axes.

### Architectural Examples

Though all buildings have all five of these properties, we will focus on each one of them in separate examples to understand them better. The courtyard elevation of the house of Rondane Bey in Tunis (1.6, 1.7) demonstrates how number is fundamental to organizing elements of an architectural composition and establishes repetition and rhythm. Geometry operates at many levels of composition but in some cases it is strikingly evident in the forms of masses and voids, such as in the Church of Saint Michael in Hildesheim, Germany (1.8). A close analysis of even complex designs, such as the Schröder House by Gerrit Rietveld (1.9) reveals an underlying proportional system; in this case, the golden mean operates in plan and section. Hierarchy may manifest itself in buildings in various ways; one way is in the massing of forms, such as in the case of the Süleymaniye Mosque in Istanbul (1.10). An example of external orientation, that is, the orientation of a building to something outside of itself, is the position of the main prayer hall of a typical mosque that, like the three examples in Tripoli (1.11), directs the users of the building toward the Kaaba in Mecca for prayer.

Number, geometry, proportion, hierarchy, and orientation operate at all scales of architectural design. For example, a door in the house of Ibn Arafa in Tunis (1.12) is an elegant composition, balanced and varied in its forms and materials. Underlying its appearance, however, we find the five basic properties at work. It has three major parts nested one within the other (1.13), a geometry limited to related circles and rectangles (1.14), a proportional system based on the equilateral triangle (1.15), a hierarchy of forms from the center outward (1.16), and an orientation based on a centerline of symmetry as well as an indication of front and back (1.17).

Two building plans illustrate how architects have used the five properties to order their compositions. The 14th-century Certosa del Galluzzo (1.18) is divided into two major parts, each with subsidiary numerical organizations (1.19); it adheres to an orthogonal arrangement of similar rectangles (1.20) within a generalized proportional system based on equilateral triangles (1.21); a strict hierarchy governs the relations of its parts in respect to both masses and voids (1.22). And each of the two major parts of the plan has a distinct method of orientation; the one for the monks is based on the centerline of the cloister and meeting room, while the one for lay people is a series of orientations that control a processional (1.23). The proposal for a courtyard house by Ludwig Mies van der Rohe is equally rigorous compositionally (1.24). Numerically, it is two figures, one superimposed upon the other, that produce three zones (1.25). Geometrically, it is restricted to relations between circles and rectangles (1.26). The rectangles emerge from the superimposition of squares and rectangles produced by equilateral triangles, that is, in the proportion of  $2:\sqrt{3}$  (1.27). Hierarchically, Mies made a clear distinction between the formal courtyard, as it relates to an interior space, and the service courtyard (1.28). Finally, the system of orientation is a series of carefully controlled segments of a processional from the exterior through the interior (1.29).

Use of the five properties of composition as the foundation of a design method does not constrain creativity; it liberates creativity from arbitrariness by providing a realistic and systematic basis for decision making at an early stage in the design process. A successful design is going to rely on these properties anyway; all of the projects in this book have these properties, whether they are by famous architects or by vernacular designers. It is therefore best to be conscious of them from the outset and use them proactively, because the first decisions made are the most critical to a design's logic.





#### 1.6

#### Number: House of Rondane Bey, Tunis. Courtyard. Elevation.

Number plays two roles in architectural composition. First, the designer arranges parts of a composition in some way—sequentially or repetitively—producing rhythm. Rhythm, which is the relation of similar and dissimilar parts, is in essence an arrangement of numbers. The second role of number is symbolic. For example, numbers connote unity, a duality, a triumvirate, or in the case of the four-quartered square, an ideal form of the terrestrial world.

#### 1.7

#### House of Rondane Bey. Diagram.

In this example, the composition has three parts, left to right, subtly indicating two similar bays flanking one central bay. The architect divided the composition vertically into two zones, the top one, in turn, into three and the lower one into two. Despite the simplicity of this arrangement, the rhythm appears complex when scanned both vertically and horizontally.



#### 1.8

### Geometry: Church of Saint Michael, Hildesheim, Germany, 1010–33. View.

In this example of early Romanesque church architecture, the geometric conception dominates the form. The plan is a basilica with two choirs (one at each end), two crossings, and two pairs of transepts. The crossings are square in plan; the dimensions of this square produced the planning module for the entire church. With clean, crisp edges, minimal apertures, and unadorned wall surfaces, it is a tour de force of elemental three-dimensional forms: cubes, cylinders, pyramids, and cones. Destroyed in World War II and rebuilt in the 1950s, the church is now a United Nations Educational, Scientific and Cultural Organization (UNESCO) World Cultural Heritage site.



### Proportion: Schröder House, Utrecht, Netherlands, 1924. Gerrit Rietveld. Plan and section.

Despite the complexity of the design, Rietveld relied on a traditional proportion for the building as a whole: the golden section is the basis for both the plan and the section. (Note that these two drawings are at different scales.) The rationale for the use of an abstract ratio such as the golden section has two theoretical bases. First, since much of the natural world appears to be ordered by the golden section (including our own bodies), humans are presumably predisposed to find it aesthetically pleasing. The second theory is that because it can be subdivided systematically to produce identical ratios at different scales, its use achieves a harmonic relation among the parts of a composition.

#### Hierarchy: Süleymaniye Mosque, Istanbul, 16th century. Mimar Sinan. View.

The center of this large complex of buildings is a mosque. Sinan perfected a compositional system, derived from Byzantine precedents, by which relatively small domes, half domes, monumental arches, and buttresses supported a gigantic central dome. The result is a powerfully hierarchical composition that produces a cascade of volumes from the center to the periphery. In its entirety, the composition harks back to an ancient Asiatic metaphor of the cosmic mountain that connects the terrestrial world with the cosmos.

#### 1.11

### Formal Orientation: Three mosques in Tripoli, Libya. Plans.

A formal orientation of a building, as distinct from a processional orientation, fixes internal elements of a plan to an external phenomenon—for example, a cardinal direction, another building, or a view. As with all mosques, in this case it is a distant referent, the Kaaba in Mecca. Left to right: Ahmed Pasha Karamanli, Carruba, Gurgi.









### Door: House of Ibn Arafa, Tunis, 19th century. Elevation.

The door is of bronze and copper within a finely detailed limestone portal that is, in turn, within a rougher limestone panel of the facade.

#### 1.13

#### Door. Number.

The composition consists of three portals descending in scale, one within another.

#### 1.14

#### Door. Geometry.

The geometry relies on the relation between a set of similar rectangles and a set of circles.



#### Door. Proportion.

The circle that forms the arch is the key to the proportional system. It is replicated twice, with the circumference of each of the new circles above and below it passing through its center, producing two vesicas and a matrix of equilateral triangles. This order establishes the positions of all major features of the composition.

#### 1.16

#### Door. Hierarchy.

The bronze door is the primary figure, the surrounding arched portal is the secondary figure, and the rough limestone portal is the tertiary figure. A constellation of minor objects, such as decorative plaques, apertures, and door handles, surround the major elements of the composition.

#### 1.17

#### Door. Orientation.

A central axis of symmetry organizes all elements of the composition monumentally and implies a formal order beyond.











#### Certosa del Galluzzo, near Florence, Italy, mid-14th century. Plan.

Niccolò Acciaiuoli, the scion of a prominent Florentine banking family, founded the large complex of buildings in 1341. Through later additions and modifications, it became an important example of late Italian Renaissance architecture and art. Pontormo contributed paintings and frescoes for the cloisters when he took refuge there from the plague in 1523–25. The plan follows the austere prescription for the Carthusian order, with each monk living in a small Lshaped house with a garden, a rationalist approach to domestic life that influenced Le Corbusier's design for the Unité d'Habitation projects in Marseilles and Berlin.

#### Certosa del Galluzzo. Number.

A continuous transverse wall divides the complex into two parts, each one focused on a courtyard. To the south are all of the buildings associated with the lay brothers and secular visitors, including the church, while to the north of the wall is a large courtyard with an arcade on four sides that exclusively served the resident monks.

#### 1.20

#### Certosa del Galluzzo. Geometry.

Despite a great variety of building types and functions, the entire plan is composed of rectangles that do not intersect but are adjacent to one another.

#### 1.21

#### Certosa del Galluzzo. Proportion.

The predominant proportional feature of the composition is a rectangle with the ratio of  $2:\sqrt{3}$ . The ratio also determines the positions of the two entrances—one at the top of the approach ramp, the other opposite the church entry.

#### 1.22

#### Certosa del Galluzzo. Hierarchy.

The church and the courtyard dominate the great variety of buildings and spaces in the south half of the plan. To the north, hierarchy is less obvious; from the courtyard, all of the monks' residences appear equal, though the ones at the northwest and northeast corners enjoy larger gardens and the interior of the northeast residence is slightly larger as well. With this apparently uniform boundary, the focus of the courtyard is the small rectangular cemetery on the south side.

#### 1.23

#### Certosa del Galluzzo. Orientation.

The two halves of the composition have different types of orientations. An axis of symmetry that passes from the courtyard into a small cloister organizes the northern half; from the small cloister, monks could access the chapter house to the west and the choir of the church to the east. Orientation in the southern half is not axial, but rather processional, that is, a series of segments of movement from the exterior into the church.















#### Brick Courtyard House Proposal, 1934. Mies van der Rohe. Plan.

The house, one of several hypothetical designs by Mies from the 1930s, is a composition of glass planes and thin nonbearing brick partitions beneath a flat roof supported by six slender steel columns. It occupies part of a paved space enclosed by a brick wall in which a single opening serves as the pedestrian entry as well as a driveway. The position of the house divides the enclosed space into two courts: a service court to the left and the formal court associated with the house's interior to the right. An exterior circular stair in the service court leads to the roof. In the interior, an arc of service spaces-including the garage, kitchen, and bath-separates two leisure spaces: a formal one defined by four columns facing the formal court, and a more intimate space centered on a hearth at the rear of the house.

#### 1.25

#### Brick Courtyard House Proposal. Number.

In this composition, number can be interpreted two ways. On the one hand, Mies divided the rectangular enclosure into three zones: service court, house, and formal court. On the other hand, the composition implies that the house is an autonomous form applied to a single preexisting tiled enclosure, thus creating a dialogue between only two elements.

#### 1.26

### Brick Courtyard House Proposal. Geometry.

The plan is an abstract composition of circles and rectangles similar to contemporary Neoplasticist paintings by Piet Mondrian and Theo van Doesburg, as well as to the Constructivist compositions of Kasimir Malevich and Alexander Rodchenko.













#### 1.27 Brick Courtyard House Proposal. Proportion.

There are two geometries working in tandem. The entire enclosure is in the proportion of 1:2, that is, two squares, whereas the house and the formal court are each  $2:\sqrt{3}$  rectangles. The difference between, or the remainder of, these two systems determines the width of the service court.

#### 1.28

#### Brick Courtyard House Proposal. Hierarchy.

Mies denotes the primary hierarchical position of the main interior leisure space by defining its four corners with four steel columns. It is directly, that is axially, related to the exterior formal court. The two interlocked squares establish the hierarchy of the entire composition: the served and service spaces.

#### 1.29

#### Brick Courtyard House Proposal. Orientation.

1.29

There are two types of orientation operating in this composition: formal and processional. A concave partition terminates an axis that establishes a formal orientation through the main living space and its court. The processional orientation consists of three segments of movement: the approach to a gap in the street facade, a right turn into the house, then a left between the end of a reception space and a column and into the main interior leisure space. A convex partition terminates this sequence of movements.