X

PROPORTION IN DESIGN

1. *Geometrical Proportion*

THE evolution of proportional dogma has been traced. If all the threads in the tangled skein have not been wound up, the ends of the main threads, the three longest of which may be labelled as embryonic construction, residues of past experience, and blind respect for authority, have been identified. Incidentally, the inconsistencies that come about as between formally constant proportion and structurally functional proportion, when scale is changed, have been made clear.

Geometric proportion, as such, remains to be considered; also the interest people in general, and architects in particular, take in the proportions of buildings, and of the parts of buildings. The question of how this interest arises, likewise demands attention.

Two triangles are said to be 'similar', no matter what the difference in their areas, when the three angles of the one are equal to the three angles of the other, 'each to each', as the old school-books say. In such triangles the sides about equal angles are in proportion. If *ABC* are the sides of a large triangle and *abc* the respective sides of a small similar triangle, the angles between *A* and *B*, and *a* and *b* are the same, and the relation of these sides may be expressed thus:

$$\frac{A}{a}=\frac{B}{b}, \text{ or } \frac{A}{B}=\frac{a}{b}, \text{ or } A:B::a:b, \text{ or } a:A::b:B, \text{ \&c.}$$

It is not the lengths of the respective lines under consideration but the ratios of the lengths of pairs, or groups, of lines with which proportion is concerned. These ratios may always be expressed algebraically and usually arithmetically. Any rectangular figure can of course be subdivided into component triangles for proportional analysis by the simple process of joining opposite corners.

It follows that parallelograms, of any areas, are similar if they are such that when diagonals are drawn connecting the acute or obtuse angles (or in the case of rectangles, any opposite angles), such

diagonals make equal angles with the corresponding sides of the parallelograms. It follows, also, that in the case of rectangles which are similar, and similarly placed (e.g. long or short sides up), no matter what their size, the diagonals will be parallel. All circles are similar in the above sense, no matter what their areas: all sectors are similar if the radii involved form equal angles at the centres, and all segments are similar if they are such that the chords and the tangents, at the point where the chord and circumference meet,

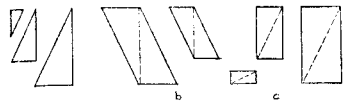


FIG. 47.

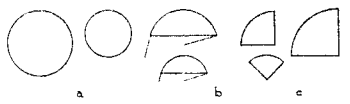


FIG. 48.

FIG. 47. Proportionate rectilinear figures.

FIG. 48. Proportionate sectors and segments.

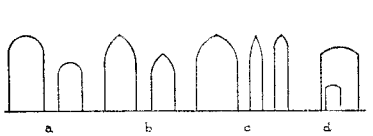


FIG. 49.

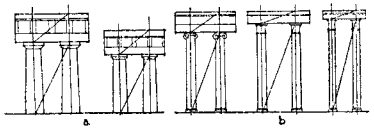


FIG. 50.

FIG. 49. Proportionate arches, *a*, *b*, *d*. Disproportionate arches, *c*.

FIG. 50. Proportionate orders, *a*, and disproportionate orders, *b*.

make equal angles. It is not the areas of figures but the shapes that are under consideration. And so with other figures, regular or irregular. It will be observed that to ascertain whether two quadrilateral figures are 'similar', in this sense of having the same proportions, it is only necessary to place them in the same relation to a line, and then consider whether the diagonals are parallel, in which case the proportions of the figures are constant.

Certain dimensional units such as feet and metres, and certain proportional relations, are commonly used in the setting out of buildings from motives of technical convenience, and these may be described with advantage before going farther.

The square 1 to 1, the double square 1 to 2, and such relations for the sides of rectangles as can be expressed as 3 to 4, 3 to 7, 4 to 10, and so on, are the simplest.

The relation between the side of a square and the diagonal is one of frequent occurrence because it is so easy to set out, however

difficult to calculate. This relation, if the square is unity, may be algebraically expressed as follows:

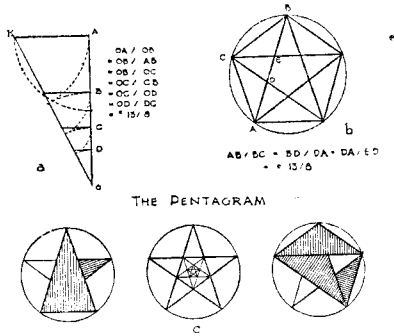
$$\frac{\text{side of square}}{\text{diagonal of square}} = \frac{1}{\sqrt{2}}.$$

A second pair of dimensions in the same ratio may be found by taking the diagonal of this first square to the diagonal of the square set upon it. A series of dimensions in continuous proportion can be found by this construction, and starting with unity, the series will be as follows:

$$1 : \sqrt{2} : \sqrt{4} : \sqrt{8} : \sqrt{16}, \text{ \&c.}$$

Another commonly used and time-honoured proportion is known as the 'Golden Section'. In this case the lesser dimension is to the greater as the greater is to the sum, or

$$\frac{a}{b} = \frac{b}{a+b} \text{ algebraically.}$$



THE PENTAGRAM

FIG. 51. The Golden Section and the Pentagram.

It will be observed that again a series of dimensions in continuous proportions may be found by an easy geometrical construction involving the pentagon. Such a series as this may be continued upwards or downwards in value. For instance, starting with 100 for convenience as the sum of two dimensions in 'extreme and mean ratio' (the modern name for the Golden Section) we get a series approximately as follows:

$$\frac{61{\cdot}805}{100{\cdot}000} = \frac{38{\cdot}198}{61{\cdot}805} = \frac{23{\cdot}607}{38{\cdot}198} = \frac{14{\cdot}501}{23{\cdot}607} = \frac{9{\cdot}017}{14{\cdot}501} = \frac{5{\cdot}574}{9{\cdot}017}, \text{ \&c.}$$

It will be well for a moment, before going farther, to consider the relation of the purely linear proportions dealt with so far, to the areas of figures and the contents of solids. It is only necessary to recall that two squares, the one on a 2-ft. base, and the other on a 3-ft. base, vary as to their sides in the ratio 2 : 3, as to their areas in the ratio 4 : 9, and as to their cubes in the ratio 8 : 27. Between

these ratios there is a relation but it is not one of constant proportion such as that expressed by the numerals:

$$2 : 3 :: 4 : 6 :: 8 : 12 :: 16 : 24.$$

Now the design of structural members in relation to their functions is largely a matter of proportioning areas to stresses, and the calculation of loads by cubic weight. This is a fundamental part of design—the discovery of form.

At Stonehenge a pair of upright stones carry a third, dividing its weight equally between them. If the two standing stones are the same in cross-section, they are equally stressed; their stresses are proportionate to their loads as between themselves.

The proportioning of areas to loads and stresses of various kinds is another matter. That is done by considering the stress the material will bear without failing, and allowing a factor of safety to allow for invisible defects, or faulty workmanship. The factor of safety may be one-sixth, or one-tenth, or some other fraction of the stress the material can stand. In designing the spars and rigging of a racing yacht, a very small factor of safety, sometimes none at all, is allowed. In structures, a member is well proportioned when its ultimate strength and a judiciously determined factor of safety are both taken into consideration with a knowledge of what the stress is.

When similar members under similar stresses have similar dimensions, they are proportionately stressed, and when dissimilar members under dissimilar stresses are stressed to the same extent they are again proportionately stressed, and necessarily differently dimensioned if the material be the same. All the members of a structure may be proportionate in this sense. Consistency is the ideal. The different parts of a member may be differently stressed, as in the case of a cantilever with a weight on the end, or a cylindrical column with a weight on the top, and this weight plus its own weight to support at the base. In such cases equal stress may be provided for by varying the depth of the cantilever from point to point, or the diameter of the column from point to point. This was the underlying idea in giving a taper to the stone column. The wood prototypes of these columns tapered the other way, probably because they were driven into the ground; less cutting was thus required in making the point.

It was seen that structural devices, such as columns carrying

entablatures, which are similar in form or have the same proportions, but which differ in scale, are not equally stressed. For example, the columns of the peristyle of the Parthenon take about double the load per square inch that those in the wings of the Propylaea do. Neither is overstressed, but the formal proportions in both orders are similar; in the greater order the column has about half the factor of safety of that in the lesser order; that is to say the functional proportions vary.

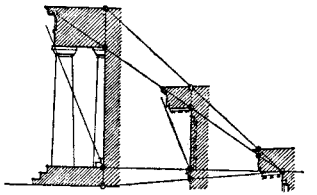
So simple an element as an arcade of four bays, with a fixed height and pitch for the piers, occurring in a wall of given thickness and height, would differ considerably, if designed for Caen stone and for granite piers with the same factor of safety. Material as well as size has its effect on form.

2. *The Appreciation of Building*

What are the circumstances under which building, regarded as an art, makes its appeal? On the stage the action which accompanies the spoken word goes on till the fall of the curtain. A picture is sought out, looked at, and left. Few can really live with a picture, and few pictures continue to be really lived with, for, with familiarity the interest wanes. The wandering tourist never gets what matters most out of the monuments he inspects so conscientiously. Even if the wanderer is a student of architecture, the mixed bag that he gets on visiting a city, new to him, is poor shooting and affords an indigestible meal. Architecture is best absorbed frequentatively and within the fabric of the daily life. It is only the buildings we pass often, the buildings we see from our work-room windows, and the buildings we use for habitation, work, play, and worship, in which we can take a full delight, or whose existence we can actively deplore. Of other buildings elsewhere we may say that we do, or do not, know that they exist; and in the former case may assume that those who use and see them often may take delight in them, but we cannot know the delight they afford. Of our familiar buildings we may say that we know them, as we know our friends, with all their faults perhaps, and that their façades have habitual expressions even as the faces of our friends have—sad, stern, serious, serene, smiling in the teeth of fate, or just happily gay. And some buildings that we cannot make our friends are dull, or inscrutable, or glum, or just stupid to us.

3. *Recurrent Forms*

Taste is largely rooted in experience and affects both the artist and those who contemplate his works. In the case of the artist, experience of his own work, or rather of his own working, engenders habit; and it often comes about that artists tend to repeat themselves, using certain analogies of form recurrently throughout their designs, sometimes illogically. Thus the Greek designers of the Doric tradition, working for centuries with an elementary, artificial, and restricted system of construction, repeated the section of the portico in the frieze and cornice and again in the upper member of the cornice. This has some virtue, but it is idle to suppose that it was done on purpose; and its virtue certainly does not depend on the numerical relation between the vertical element and the horizontal element. What virtue there is, is of a negative kind. No new form obtrudes on the attention. The characteristic form is echoed. The thing has a sort of law of its being, as some trees have, whose usual profile is echoed in the form of the leaf.



THE PARTHENON

FIG. 52. An interesting case of analogy of form elucidated by Prof. August Thiersch, *Handbuch der Architectur*, ed. 1904, iv, p. 43.

The miniature decorative architecture which adorns the actual structural architecture of fourteenth-century building in England is another case in point. That this was done on purpose and by rule in the case of the Greek, and out of the exuberance of his heart by the Goth, has never been proved, though suggested by writers on each period. But it must be borne in mind that the men who conduct researches on Greek or on Gothic art are cast in more fundamentally different moulds than the artists of either era. The thing was probably unconscious in either case. Perhaps it had something in the nature of an exhausted invention in both. In any case it was sound practice and imparts to many a building a quasi-organic unity. Much the same sort of thing is to be noted in many other kinds of architecture. When consciously applied, as it no doubt has been by the recondite architects of sophisticated eras, recurring analogies of form at varied scales, but in constant proportion, afford a potent artifice for unification.

And so it is with our double squares and that favourite ratio of the side of a square to the diagonal, and with the Golden Section. There is no virtue in these relations, or in integral numerical relations as such, and it is the purest superstition to believe otherwise. Yet many a building possesses a dignity, a serenity, a sense of stability, or some other distinctive character, because of the habit of its designer in the matter of the Golden Section or the double square. But any other ratios natural to the structure which might recur dominantly would have served equally well. It is not the ratio but the fact of its recurrence that matters. Without recurrence there can be no rhythm; and rhythm provokes mood.

It has already been shown how two similar rectangles can be made to appear very different by dividing up the one horizontally and the other vertically. Not only is the eye quite unable to appreciate slight differences of ratio in rectangles of about equal area, occurring in different stories of a building, say the one of 1 to 3 and the other 2 to 7, but similar rectangles occurring in different parts of a building usually do look dissimilar owing to minor subdivision, or the exaggeration of character due to contrasting forms in their proximity. When foreshortening due to height and the diminutions and distortions of other perspective effects—to say nothing of optical illusions—are taken into consideration, it will readily be realized that in a building, even of the simplest description, things are rarely what they seem in the matter of dimensional relations.

The student who measures and then sets out a drawing of an existing building experiences a series of valuable surprises, particularly if any considerable dimensions of height are involved. He realizes, in a way he never could by drawing the thing out to a different scale from a plate in a book, that architecture is a trade full of tricks. This realization lays him open to the wiles of the facile astrologers who prate of perfect numbers and the secrets of proportion. Proportion is more difficult to master, but far less mysterious than the necromancers would have us believe.

When dealing with composition, there will be something to say of the artistic use of proportion in contrast, in analogy, and in climax.

Buildings make their proper appeal when their precincts are frequented. They are designed to be seen in ever-changing perspective, and in ever-changing lights. Under these conditions there is a premium on general simplicity. They are, moreover, felt as

masses, not as the shells they really are. The complication of subordinate detail may be infinite in a thousand ways, but it is a condition of effect that the detail should reinforce the character of the whole. The devices of proportion can find abundant employment in this intensification of character. The building that lacks character, whatever interest of prettiness, or charm, it may possess to attract the attention of the vagrant tourist, does not grip the spirit of those who know it as part of their daily environment.

4. *Formal and Functional Proportion*

How have all these misconceptions arisen? There are two quite distinct senses in which the word function may be used in reference to a design, whether executed or not. First there is function, meaning the use of the thing, its purpose or purposes: in the case of a building the use may be habitational, or ceremonial, and so on, and the several rooms, or parts, will have their specialized functions or uses, such as entertainment or ritual. Secondly there is function dependent on structural consideration arising from material and technique: in the case of a building, vertical support in the columns, piers, and walls, and horizontal support in the beams, arches, trusses, and other members.

Now those who frequent buildings are very good judges of proportion with respect to function in the first sense. They readily realize the relation of length, breadth, and height to purpose in the case of a dining-room or a church. They are the best judges of good proportion in such matters. They are quite properly indifferent to ratios. The height and breadth might be equal and the length double the breadth, but this would and could make no difference to the judgement. Would make no difference; because the belief that it is a privilege to be allowed to stand on the floor of a double cube room is not widespread and when it occurs rests on illusion and bad authority. Could make no difference; because even if the frequenter were an expert juggler in proportions (as every architect should be) he could not without measuring rod ascertain that he was indeed in a double cube room.

But where structural members are in question and the function relates to structural use as distinct from general purpose, the man in the street is not a good judge of proportion. He assumes equal, or at least adequate stability in anything with walls and a roof that is not in ruins. In such matters the architect bases his judgement

very largely on precedent, and only interests himself in factors of safety and stresses and loads where the structure is abnormal in type or in precarious condition. The engineer, on the other hand, distrusts his eyes and prefers his slide-rule and some ascertained facts before he passes any judgement at all. Structural inconsistencies of the grossest kind are thus readily acquiesced in by the general public, architects, and engineers alike. In a structure whose frame may have been calculated with the greatest precision and consistency, one often finds colonnades in which the factor of safety may be anything from three to three thousand. The probability in such a case is that the colonnade is not conceived as part of the structure, but as a piece of rhetoric which, if bound at all, is only bound by formal as distinct from functional proportion.

We all count it to him for grace when a finance minister mitigates his unpalatable facts with the flowers of rhetoric, so long as he does not obscure them; and we welcome the homely similes with which the astronomers of our day delight to make their popular expositions of unthinkable voids and unimaginable masses. So, in design, some poetic licence must be accorded to the designer when he begins to concern himself not only with the thing but with how he feels and wants other people to feel about it. This is where architecture begins; or, if you like, where pure design ends.

5. *Scale and Proportion*

For the realization of the actual size of objects, great and small—always an important element of effect—there are two distinct methods open to the designer. These may be combined intentionally. They must inevitably be mixed to some degree. But there is choice as to which shall dominate. The one is based on proportion, the subject now before us; the other on scale, which has been dealt with in a preceding chapter. The classic Mediterranean tradition in design relies very markedly on consistency of formal proportion, while the Gothic, or northern medieval tradition, relies chiefly on consistency of scale. The Greek of a given place and time would thus, as has been seen, use columns of approximately the same shape, whether they were 35 ft. or 17 ft. in height, while the Goth would use one or two lights to form a small window and eight or nine lights, each about the same size as in the small window, to form a big window. In the one case you require the presence of a fixed unit, say a man, to enable you to realize the size of the colonnade; in the other, the unit of measurement pervades the structural element in question, or even the whole fabric.

But, in stressing the principle of constant proportion in classic architecture, it is often forgotten that Greek and Roman builders, if a little blind to structure-function, were at least as sensitive to use-function as the builders of sailing ships in recent times. A small ship may have one or two masts, a big ship three or four, and a ship of the kind developed at the end of the last century, too big to live long, might have five or six. So with the temples. The small ones had fewer parts. One could not get in or out of the temple of Nike Apteros if it had eight columns on the front of it, and one could not work a 40-ft. boat with three masts and topgallant sails. There are practical size limits to formality.

6. *Conventional Proportion*

It must not be inferred from anything said above that the proportioning of structural elements without close reference to engineering consistency is either aesthetically or ethically reprehensible, although it may be practically and economically reprehensible. But the designer should at least know what he is doing and be in a position to realize wherein his building, or his chair, is merely expressing its own essential structural facts and wherein it is expressive of his feelings about its structure and its use. Inherent functional proportion should be clearly distinguished, in the mind of the designer at least, from arbitrary, conventional, or intentional proportion.

Design in all purity is manifest in nature. With an approximation to purity it is the aim and object of the engineer and the constructor. With artistic modification superadded it is the achievement of the artist. But, even when building is the matter in hand, this increment of artistry does not necessarily involve recourse to architecture; although usually it does. For what is architecture but a systematic code, made up of forms consecrated by the accidents of tradition. So when recourse is had to this code it is well to remember that it is essentially systematic—that it has a grammar of its own—that its standards of pronunciation may be illogical like those of cultured speech—but that rhythm in form, as in diction, is dependent on just that kind of standardization and convention with which Sir Philip Sidney and the early Elizabethans so wisely concerned themselves.

It has been more than hinted that those who explore the secret

proportional relations in the structural elements of ancient buildings often delude themselves and others. Now it is boldly asseverated that design without proportion is a salt without savour, and architecture without proportional standards is unthinkable. How does one reconcile these attitudes?

7. *The Proportional Fallacy*

The claim that this, or that, or these several proportional relations, such as the 2 to 1, the 1 to $\sqrt{2}$, or the Golden Section, has an aesthetic or hedonic value is readily met by recalling that the eye, as an organ of sense, is indifferent to forms and that the mental processes of judgement which the eye stimulates require much education to distinguish rectangles having such relations and can, even then, be very easily deceived. There can be no hedonic satisfaction, direct or indirect, in such exercises.

Consider the circumstances under which rectangular forms occurring in designed objects—openings in walls for example—are seen or apprehended by eye and mind working in conjunction. The answer is: rarely, if ever, without misleading foreshortenings (horizontal, or vertical, or both) except when such forms are translated into mechanical drawings of small scale which are then held at right angles to the line of regard at a distance of from 10 in. to 6 ft. Recondite numerical relations between the width and height of rectangles can have no intrinsic values, optical or mental.

And so it is with the dotted circles struck to embrace the angles of pediments within a quadrant, and with all other setting-out lines, actual, or imaginary, which the proportionist delights to discover. When actual, his discoveries are merely the designer's original setting-out lines and geometric constructions for practical use and convenience. If an opening, still more if a series of openings, about twice as high as wide is required, it is easiest to set it out exactly so. If the foot, or the cubit, or the metre, be the unit of measurement, exact numbers are in order for convenience and need no further explanation. The ratio, side of a square to its diagonal, is a peculiarly handy one requiring one measurement and the rest instrument work. The Golden Section as a construction for setting out is not so practical. The construction has in itself something of the mysterious. The great popularity of this proportional relation could hardly have been brought about until the error of mistaking means for ends in the case of setting-out lines had become general. Possibly the undertaking to instruct one's apprentice in the 'art, trade, science, and mystery' one practised gave to the setting-out lines (which the apprentice had the job of rubbing out) an air of mystic value. The thing shown on the finished drawing was calculated: the calculation was a little mysterious: beauty, the fundamental problem of the older aesthetic, was also mysterious: the one mystery explained the other: the Golden Section was a secret of beauty! And in due course another apprentice was inoculated.

Nothing further need be said with respect to a good, better, or best in abstract proportional relations. It can never be what the proportions are that matters. It is in how they can be used by a great artist in design that their interest for the student lies. It is, of course, pre-eminently in architecture that this happens.

8. *Conclusion*

An example may be helpful at this point. There is a certain quality about the Palazzo Farnese and there is a proportional secret. Whether one appreciates the quality or not, one may be quite sure that the secret and the quality have a good deal to do with each other. The proportional secret that matters is not the fact that the dominant ratio is 2 to 1, which it is, but the much more interesting fact that one ratio dominates nearly everything. This incidentally leads to several remarkable inconsistencies in the composition, but let that pass. The prevalence is what matters, not the ratio selected; the prevalence, even if, as in this case, it is carried too far.

Repetition of similar minor elements—a row of windows for example, or a series of bays—is inherent in the solution of most problems of design for buildings. When the fabric of a structure becomes thus pervaded with a dominant repeating, functionally and structurally generated, proportional ratio, it matters not a whit what that ratio may be; but it does matter that other elements, in which proportion is at all involved, should be dimensionally related to the dominant, characteristic, recurring ratio. This relation need not be one of similarity. The rhythm of the composition may depend on the use of the dominant and one or more subordinate proportional ratios; or on a set of ratios distinctly different; or on a pair of ratios in mild, or acute, contrast.

There can be no such thing as composition, or orderly arrangement of a façade (which is usually an affair of rectangles) if it has

all its structural elements set out haphazard with respect to spacing and placing. If irregularity is an essential characteristic of the thing, as it may often justifiably be when the functions of its several parts demand such recognition, the proportional unity of the whole may yet be maintained by adroit subdivision of these proportionally heterogeneous elements. The framing of windows into lights for the sashes and the subdivision of the sashes into panes of a fixed, recurring ratio (and often of a fixed actual dimension) both offer opportunities for the exercise of this device. Much good architecture is indeed dependent on nothing else than this for its claim to a place in the realm of art.

One may be tempted to say that proportion is the thing that matters most in architecture, and one will not be far wrong; but it is perhaps safer to say that the interrelation of scale and proportion is the thing that makes composition possible. Whether the object be as simple as the Maison Carrée at Nîmes or as complex as Compton Wynyates, it is on scheme with respect to these two matters that it must depend for its unity and its character. Without unity the thing dissolves into two or more things and without character it becomes inane.