# GREEK REFINEMENTS

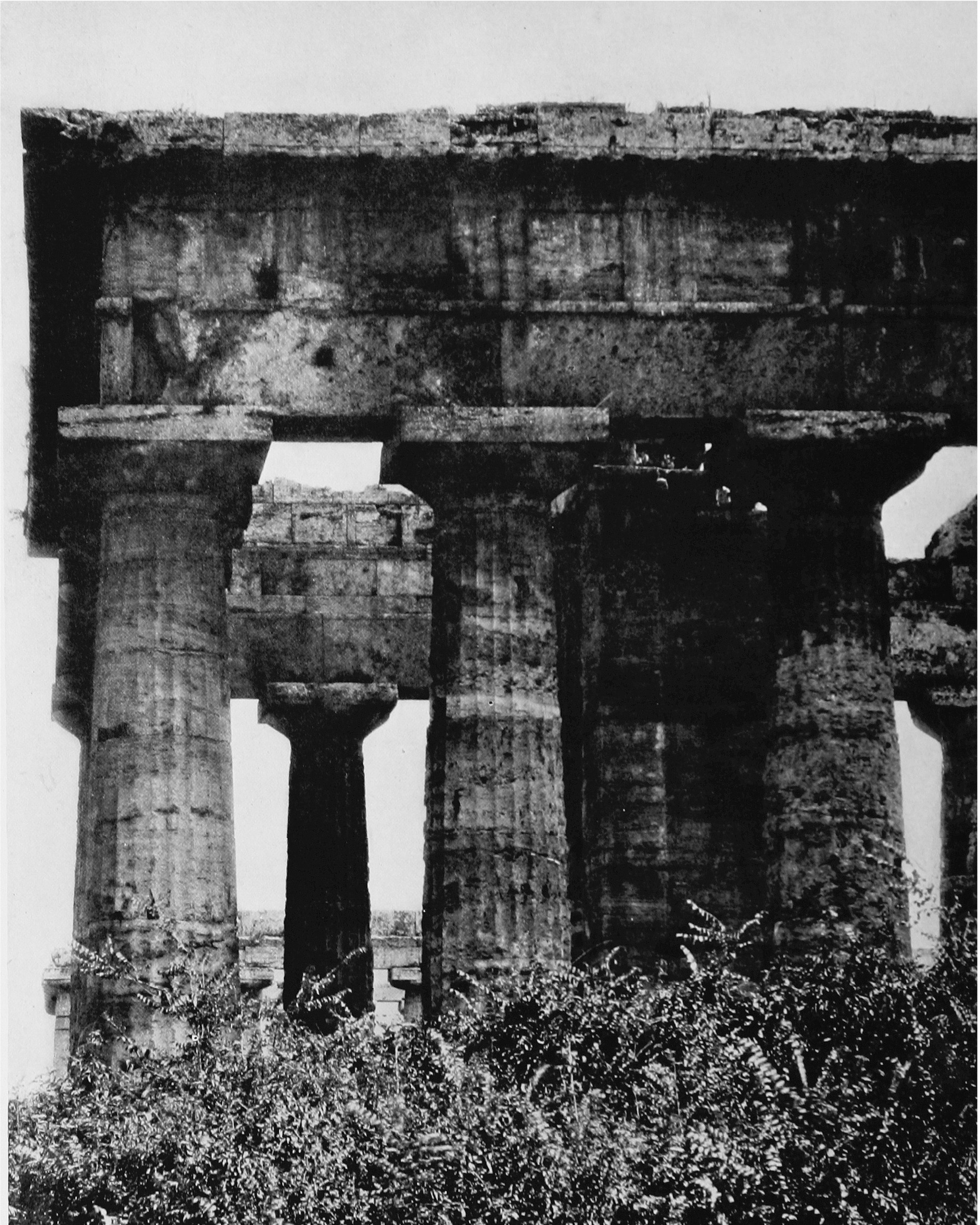

Fig. 1. Curves in Plan, Concave to Exterior, in Capitals and Entablature.

East front of the so-called Temple of Poseidon at Pæstum, looking from north to south. Brooklyn Institute Museum photograph, series of 1895.

# GREEK REFINEMENTS

## STUDIES IN TEMPERAMENTAL ARCHITECTURE

BY

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TO

AUGUST AND EMMA M. LEWIS

WHOSE SYMPATHETIC SUPPORT INAUGURATED AND CONTINUED
THE RESEARCH OF WHICH THIS VOLUME IS A PARTIAL RESULT

AND TO

FRANKLIN W. HOOPER, HENRY W. DESMOND
FRANK W. DEAS, JESSE HAWORTH, GEORGE FOSTER PEABODY
A. AUGUSTUS HEALY, WILLIAM H. CROCKER
AND E. BYRNE HACKETT

WHOSE MUCH-VALUED COÖPERATION IN THE INTEREST OF THESE
STUDIES IS GRATEFULLY APPRECIATED BY THE AUTHOR

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## PUBLISHERS' NOTE

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# PREFACE

It was in 1868, and under the tuition of Professor Carl Friederichs, then director of the Antiquarium of the Berlin Museum, that I first learned of the existence of the horizontal curvature in the Greek temples. The significance of the fact impressed me greatly, and it was during a trip to the Levant, undertaken in the company of that savant in 1869, but after I had parted company with him in Cyprus, that I first came in contact with the Athenian monuments which offer such convincing illustrations of the importance of this refinement, as far as the Greek architecture is concerned.

In the spring of 1870 the observations of Ernst Förster at Pisa, which are recorded in his Italian Guide-book[a] and in his History of Italian Art,[b] led me to an independent investigation of some of the Pisan monuments, especially of the cathedral, which materially supplemented and increased my acquaintance with the class of facts which Förster had recorded.

Meantime the pregnant suggestion of Jacob Burckhardt, in his "Cicerone,"[c] that Förster's observations, if verified as representing facts of construction and not of accident (as Burckhardt had supposed them to be), would find analogies in the Greek temples, led me to visit that scholar in Basel and to lay before him some of the measurements and sketches, bearing on purposed deflections of alignment and various optical illusions, which I had observed in Pisa. Burckhardt showed great interest in the facts made known, with which he professed himself previously unacquainted. He advised me to publish, and my plans were made at that time for an examination of the Italian and other mediæval monuments, with reference to the use of optical illusions, of constructive curvatures or bends, and of other purposed departures from formal architectural symmetry.

At a slightly later date I became acquainted with Ruskin's highly important observations as to the purposed departures from formal symmetry in Italo-Byzantine and Italian-Romanesque arcading. A publication was

[a] *Handbuch für Reisende in Italien.* 2 vols. Eighth enlarged and revised edition. Leipzig, 1869. Vol. I, p. 364.

[b] *Geschichte der Italienischen Kunst.* 5 vols. Leipzig, Weigel, 1869. Vol. I, pp. 250, 253.

[c] *Der Cicerone.* Leipzig, E. A. Seemann. Second Edition, 1869, pp. 101, 102. The passage referred to does not appear in recent editions, of which the latest is the tenth (1909). After the appearance of the first edition, Burckhardt sold his rights in the book, as personally made known to me at Basel in 1870, and the second edition, and all later editions, were edited by other hands.

also made, in "Scribner's Monthly" for August, 1874, of my observations of 1870. The article was entitled "A Lost Art."

My own plans for an investigation as to the existence of constructive asymmetries, optical illusions, and other refinements in mediæval building were, however, necessarily deferred for twenty-five years—until 1895. Since that date I have made various contributions to periodical literature on this subject,[a] and a book has also been announced as being in preparation. This volume is, in fact, the first installment of that book, although it is confined to the architecture of the Greeks, or, at least, of the ancients. The Greek temples are too far apart from the mediæval cathedrals to be coupled with them in a single volume. On the other hand, the analogies in some directions are so striking, especially as shown in the sixth chapter, and the possibilities of direct historical transmission in the case of the horizontal curvatures are so obvious, as to make a detailed and careful account of the Greek refinements an absolutely essential preliminary to a treatment of the related subject in mediæval architecture, however different in its details this subject may be.

Aside from this relation to my mediæval research, this volume is an independent unit, and may be regarded as a desirable and long-needed addition to the knowledge of Greek temple architecture, considered as a wholly independent study. Up to date there has been no book for general readers on the subject of the Greek refinements. The work of Penrose, which is our one important folio authority on the refinements of the Athenian monuments, appeared over sixty years ago, and by its size and bulk is unfitted for general readers. The very qualities which give it great value for specialists unfit it for other use than their special consultation.

Moreover, since the date when it appeared, as is shown in later chapters, a very considerable mass of additional knowledge on the subject has been accumulated, and various theories of explanation have been advanced, many of which, like those of Penrose himself, are now in need of substantial revision. But these additions to matter-of-fact knowledge, and these various theories, or the revisions which they called forth, have appeared in widely scattered and relatively inaccessible periodical and specialist publications. As regards general results, they are mainly unknown, not only to the world of culture but even to specialists. The time is thus ripe for a summary, but systematic and readable, account of this important but neglected subject.

[a] For references, see Index of Authorities.

# CHAPTER ONE

# THE MODERN DISCOVERIES

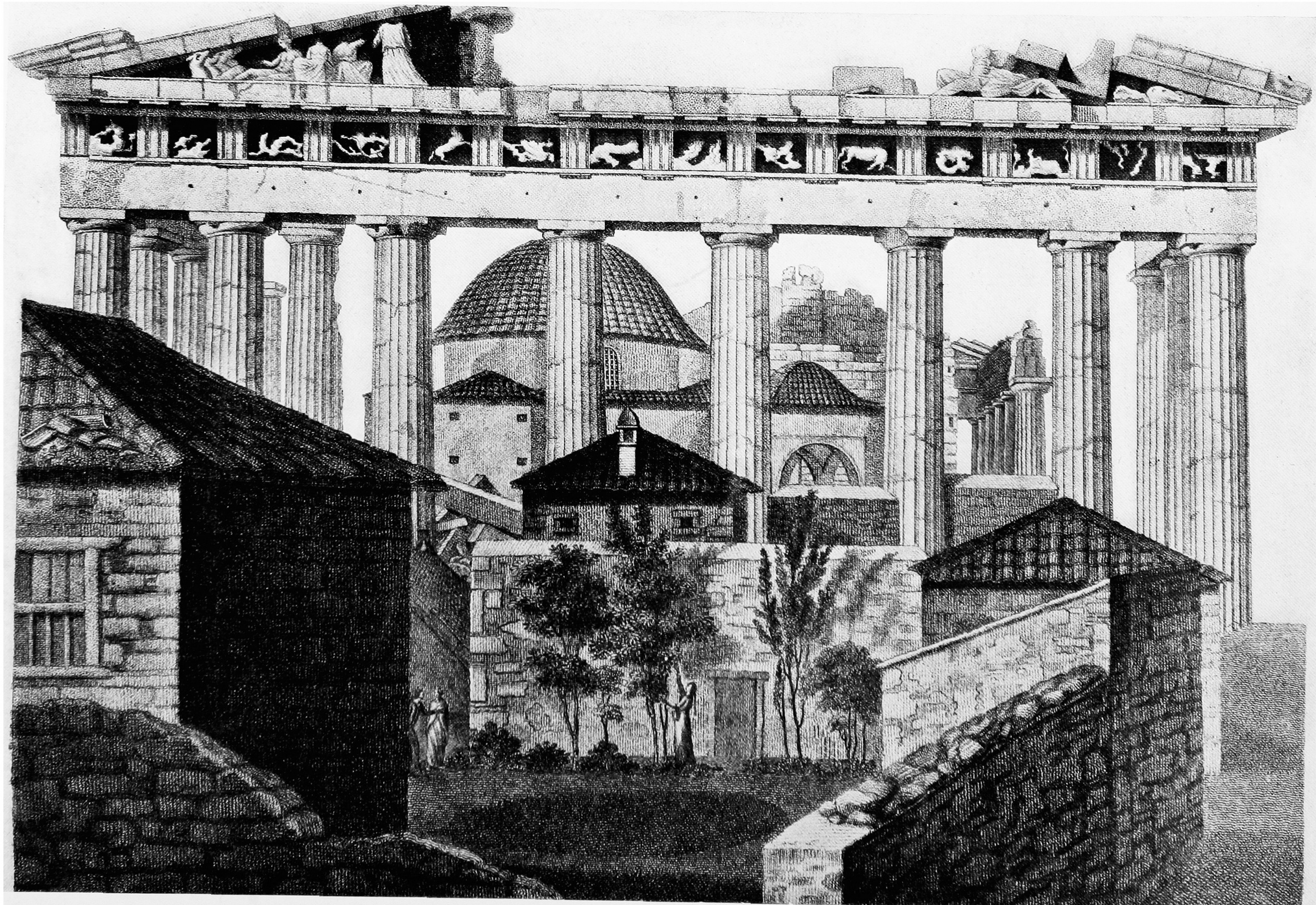


Fig. 2. The Parthenon during the Turkish Period, after the magazine explosion of 1687, and before 1829.

Showing the Mosque inside the Temple. From an old engraving, dated 1797 and published in London.
A similar, but not identical, engraving is published in Stuart and Revett's "Antiquities of Athens," Vol. II, Chapter I.

## CHAPTER I

### THE MODERN DISCOVERIES

THE term "architectural refinement" has been limited until recent date to certain devices whose use was supposed at the time of their discovery to be confined wholly to the Greek temples. The discovery of the existence of these Greek refinements is comparatively recent. They were wholly unknown to modern students until about 1837, when the horizontal curvatures of the Parthenon were observed by the English architect John Pennethorne[a] (1808–1888) and by the German architect Joseph Hoffer. The first publication on the subject was made by the latter in four numbers of the "Wiener Bauzeitung" in 1838, with many details and numerous carefully illustrated measurements.[b]

Neither one of these experts appears to have been aware, at the time, of the discovery made by the other. In his publication of 1838 Hoffer says that his observations were the result of several years' activity ("mehrjähriger Thätigkeit"), which would place his earliest observations in Athens before those of Pennethorne in 1837, and the latter has expressly stated that Hoffer's observations were "quite independent of my own."[c] As Hoffer was at this time the official architect of the recently founded Greek kingdom (then ruled by a Bavarian king), and as he had directed and superintended, in 1836, the clearing away of the rubbish from the platform of the Parthenon on which the curved lines could be most easily sighted, it is natural to presume that he was the first modern observer of the Greek curvature. Moreover, the great number of the measurements and observations which Hoffer published in 1838 would tend to verify his assertion that they were the result of

[a] John Pennethorne (1808–1888) studied under John Nash, a very distinguished architect of the late eighteenth and early nineteenth century, and at the age of twenty-two, in 1830, undertook a five years' tour in southern Europe and the Levant, as a travelling architectural student. Other details of his life will appear in the text. Some variations from a few of the dates and statements mentioned in the *Dictionary of National Biography*, edited by Leslie Stephen, have been carefully verified by Mr. Pennethorne's own accounts, in his work to be subsequently quoted.

[b] No. 27, p. 249; No. 41, p. 371; No. 42, p. 379; No. 43, p. 387, Plates CCXXXVII–VIII–IX. Edited by L. C. Förster, architect. Verlag von L. Förster's Artistischer Anstalt in Wien. Most of the observations of Penrose are anticipated in these publications, as far as the Parthenon, the Theseum, and the Propylæa are concerned.

[c] Page 81 of his book published in 1878. As regards the observations of a German architect named Schaubert, see p. 105.

several years' labor. The circumstances under which Pennethorne made his discovery, as subsequently related, make it certain, however, that it was made independently and that it was the concurrent result of reading the directions of Vitruvius for the construction of curvatures, and of having

Fig. 3. West Front of the Parthenon.

personally observed curves (of a different character) in Egyptian architecture as early as the winter of 1833.

Seven years later, in 1844, Pennethorne printed a pamphlet of sixty-four pages, for private circulation among his friends, but otherwise was unable to give any additional attention or publicity to the subject until 1878, when his "Geometry and Optics of the Ancients" appeared in a very bulky folio.[a]

[a] Williams and Norgate, London and Edinburgh. Out of print.

The first publicly printed mention of Pennethorne's observations appears to have been made in the second edition of Leake's "Topography of Athens," p. 573 (1841).

The Greek refinements were more thoroughly investigated, in 1845–6–7, by Francis Cranmer Penrose, whose publication, in 1851, entitled "An Investigation of the Principles of Athenian Architecture," continues down to the present time to be the most systematic and exhaustive description of the facts relating to this subject.[a] Its theories as to explanations must, however, be considered, at present, as subject to serious revisions. This point will be developed in the next chapter.

THE most comprehensive brief statement as to the nature of the Greek refinements would be that they are purposed departures from the supposedly geometrical regularity of the horizontal and perpendicular lines in the Greek temples, and from the presumed mathematical equality of their apparently corresponding dimensions and spaces. The most frequently mentioned of these refinements are the horizontal curvatures which are found in the platform or stylobate, in the entablature (architrave, frieze, and cornice), and in the lines of the gables.[b]

The generally quoted curves, and the only ones known to Penrose as intentional, are the rising curves in vertical planes (curves in elevation). Hoffer's announcement, in 1838, of the existence of curves in plan (*i.e.*, in horizontal planes) concave to the exterior, on the fronts of the Parthenon, in the lines of the capitals, and in the entablatures and gables (*but not in the tympanum*), has been generally neglected or discredited, because Penrose held these curves to be accidental. The very recent but well-authenticated discoveries, in other temples, of curves in plan concave to the exterior (see Chapter II) are calculated to reëstablish the credibility of Hoffer's announcement, which has otherwise, and before these recent observations, been favorably considered by the high authority of Professor

[a] Published by the Society of Dilettanti; first edition (1851), Longman & Co., and Murray; second edition (1888), Macmillan. The second edition contains many important additions to the text, and consequently has a different page-numbering. All page references in this work are made to that edition.

Francis Cranmer Penrose (1817–1903) studied architecture under Edward Blore and then graduated at Magdalene College. Following the investigation above mentioned, which he began at the age of twenty-eight, he was appointed surveyor of the fabric of St. Paul's Cathedral in 1852, a post which he continued to hold until 1897. In 1886 he was appointed director of the British Archæological School at Athens. He was awarded the gold medal of the R. I. B. A. in 1883, and was president of this society during the years 1894–5.

[b] The raking lines of the gables are curved upward in the Theseum, but not in the Parthenon (Penrose, p. 105). For bends in the opposed direction in the raking gable lines of the Parthenon, see p. 152.

Adolf Michaelis.[a] The constructive existence of these concave Parthenon curves in plan was also conceded by Reber.[b]

At this stage of our explanations it is only necessary to point out that the proven existence in classic temples of intentional curves in plan (*i.e.*, in

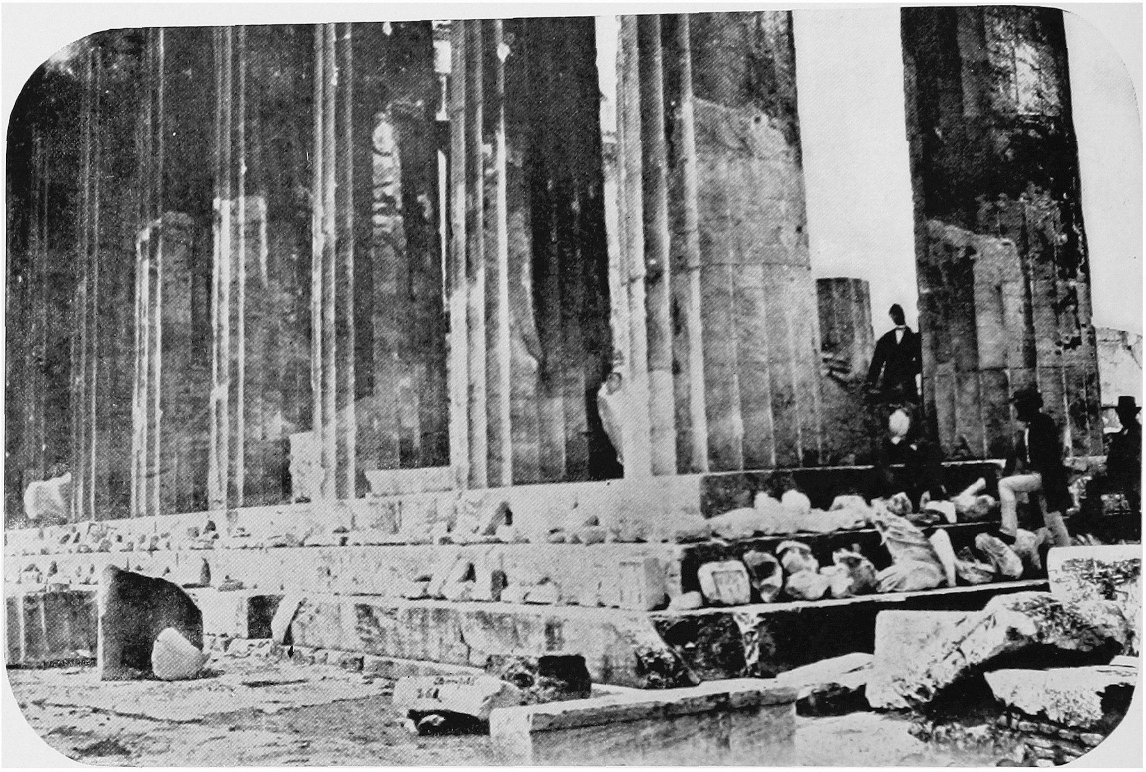


**Fig. 4. Curves in Elevation, Platform of the Parthenon, East Front.**
**From a photograph belonging to the Architectural School of Columbia University.**

horizontal planes), of which some are convex and others concave to the spectator's point of view, was wholly unknown to Penrose, and the dates of discovery or announcement will be referred to later on.

The curves in elevation, to which the attention of Penrose was exclusively devoted, have, in the Parthenon, a deflection from the imaginary and presumably straight line of about 4 inches on the flanks (about 228 feet), and of about 2¾ inches at the ends of the temple (about 100 feet).[c]

The representation of such delicate curves in book illustration is difficult. The method adopted by Penrose is to exaggerate the rising deflection by a measured drawing which makes the curve fifty times higher, in relation

[a] *Der Parthenon*, p. 19. Leipzig, Breitkopf und Härtel, 1871.

[b] *Kunstgeschichte des Alterthums* (Leipzig, T. O. Weigel), 1881, p. 207. This passage relating to the concave curves in plan is omitted from the English translation of Reber's book. See *History of Ancient Art*, by Dr. Franz von Reber. Harper, 1904.

[c] For the exact measurements of these and other curves, see Appendix[1] of this chapter.

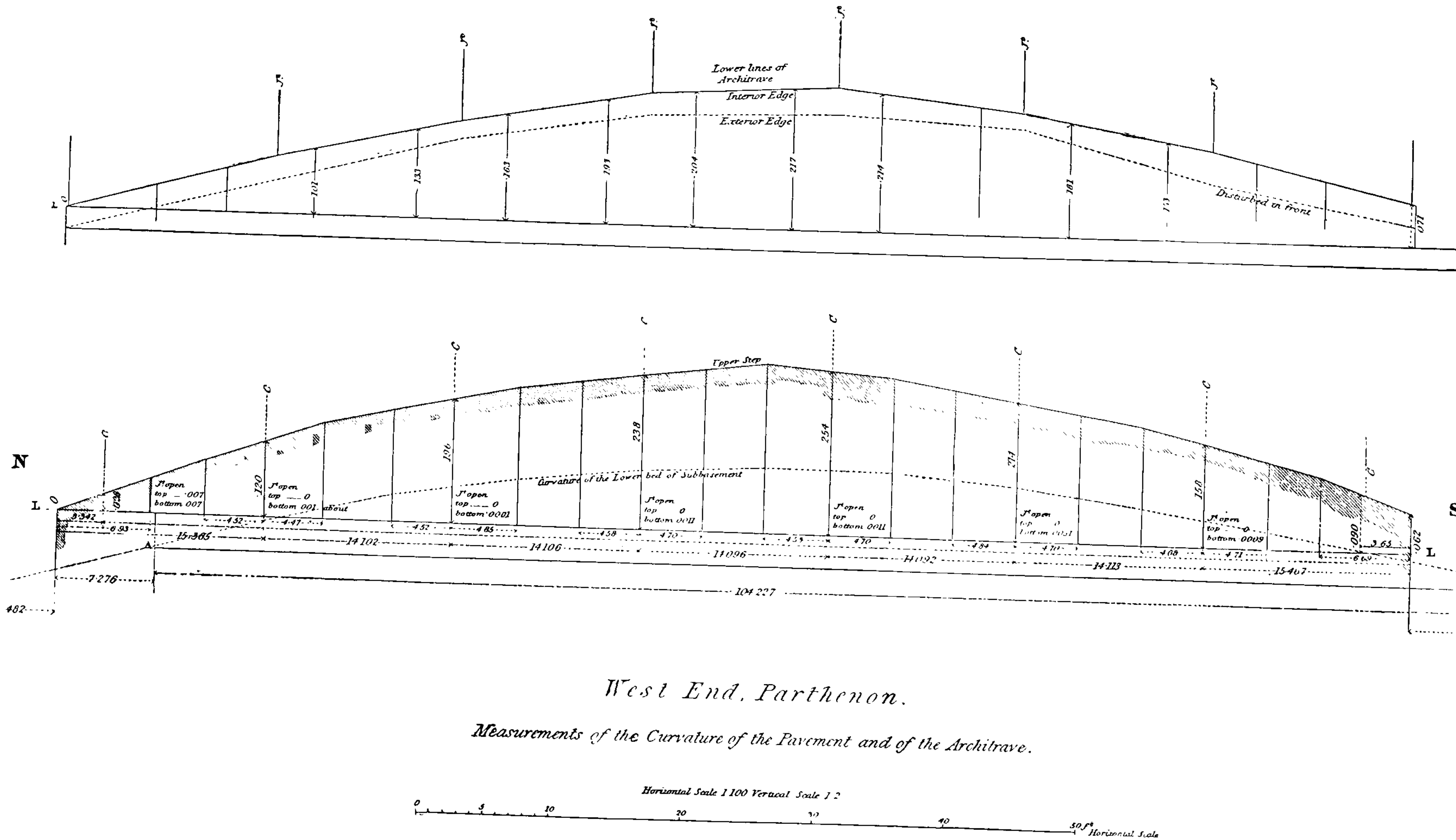



**Fig. 5.**

From Plate XI of "The Principles of Athenian Architecture." The curves are exaggerated fifty times in relation to the horizontal line.

to the true level line, than it actually is. This method is illustrated by Fig. 5, p. 7, which reproduces one of the plates from the "Principles of Athenian Architecture." When this drawing is examined it will appear that the Greek curves, so called, really consist of a series of bends in a series of straight lines. This fact has been widely overlooked, because the effect for the eye is that of true curvature. The method of illustration used by Pennethorne (whose measurements are borrowed from Penrose) is not accurate in this particular, but otherwise resembles it as regards the principle of exaggeration. See Fig. 7, p. 11.

Illustration by photography has been rarely attempted and is almost unknown in books or in periodicals, aside from publications which have been made by the writer.[a] Some notes on the sources and character of the photographs of curvature which are reproduced in this book will be found in Appendix[2] of this chapter. The reader is advised to use these half-tone illustrations by holding the page sideways, so as to sight on the horizontal curved line at the level of the eye. If the page is not held perfectly flat the curve will either disappear or be exaggerated. A page which is bent will distort the line.

There are also other variations from formal regularity in Greek temple architecture of equal importance and significance.

In the Parthenon, for instance, surfaces or members which are set true to perpendicular are exceptional. Perhaps the end walls are the only exception. All the columns lean inward toward the sides of the building, and the angle columns, therefore, lean inward diagonally. The side walls lean inward more than the columns. The antæ, or flat pilasters at the ends of the side walls, lean forward. The vertical faces of the platform steps and of the architrave and frieze lean inward, whereas the acroteria and antefixes, the vertical face of the cornice, and the vertical front faces of the abaci, or square slabs between the architrave and capital, lean forward. The door jambs lean slightly toward one another, in the rising direction.[b]

The columns and the capitals of the Parthenon are also of unequal sizes, with a maximum increase in the diameter of the columns at the angles of about 1¾ inches; in average diameters of 5 feet and a fraction. There is a maximum increase in the size of the capitals at the angles of about 2 inches; in average diameters of 6 feet and a fraction. Aside from this increase in

[a] These are mentioned in foot-note[b], p. 47, and in Appendix[2] of Chapter II, p. 71.
[b] For the measurements of these inclinations, see Appendix[3] of this chapter.
For the benefit of general readers who may not be architects or archæologists the architectural terms which occur in adjacent paragraphs are explained by descriptive definitions in Appendix[4]. See also the illustrative Figures 17–21 inc. (pp. 29–32) for this terminology.

size at the angles, there are other *systematic* variations in the sizes of the capitals, with a maximum variation of 2¼ inches. The greatest variations in intercolumnar spacing are those of over 2 feet diminution at the angles. These variations of intercolumnar spacing have elsewhere a maximum amount of about 1¾ inches, in measures which average 8 feet and a fraction. The maximum variation in the widths of the metopes (the spaces between the triglyphs on the frieze of the entablature) is about 4 inches in measures which average about 4 feet.[a]

In order to appreciate the significance of these amounts of variation

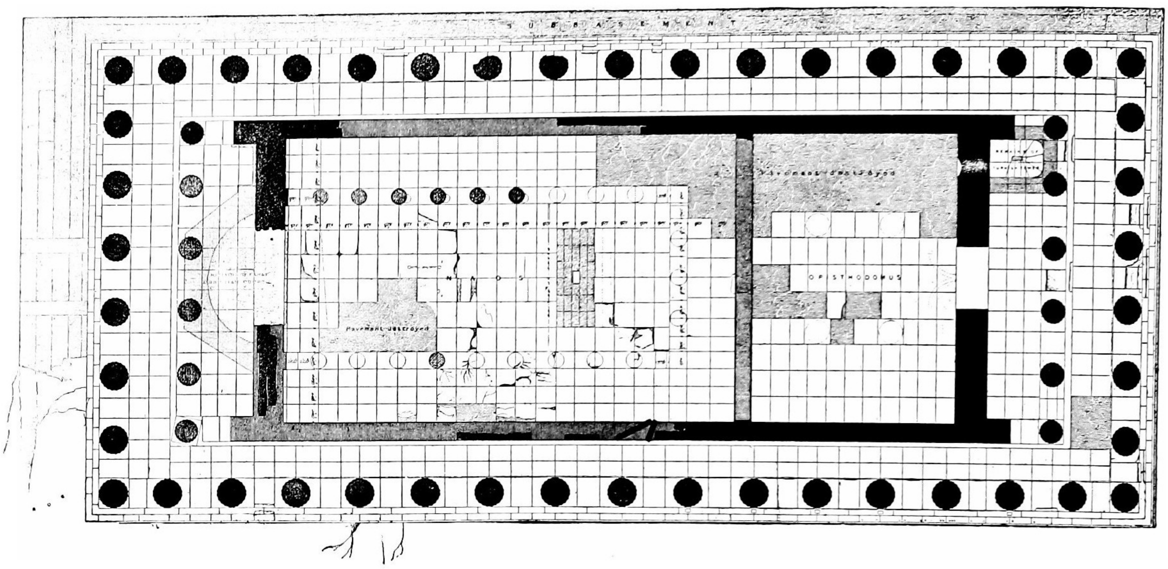


Fig. 6. Ground-plan of the Parthenon. From "The Principles of Athenian Architecture."

The under side of the plan is the north side, the east front being on the left. The heavy shading indicates columns which are still erect in entire height and well-preserved parts of the walls. The light shading in the interior indicates destroyed portions of the pavement and, on the east front, the position of the apse of the early Christian church.

from normal regularity, it is necessary to have some idea of the accuracy which was attainable by the masons of the Parthenon. On this head it may be said that the amount of variation attributable to mason's error has been fixed by Penrose at one quarter of an inch (0.022 foot), because the two fronts of the temple are equal within the limits of that variation. To quote the exact words of this author (p. 12):

The small difference of 0.022, in 101 feet, which appears between the breadth of the eastern and western porticoes, points out the degree of error which may have arisen from inaccuracy of workmanship in the Parthenon. . . . With regard to the difference of 0.022 between the breadths of the two fronts, even wooden measuring-

[a] For explanations of these variations of the columns, capitals, intercolumniations, and metope widths, see Chapter VI, pp. 190–192.

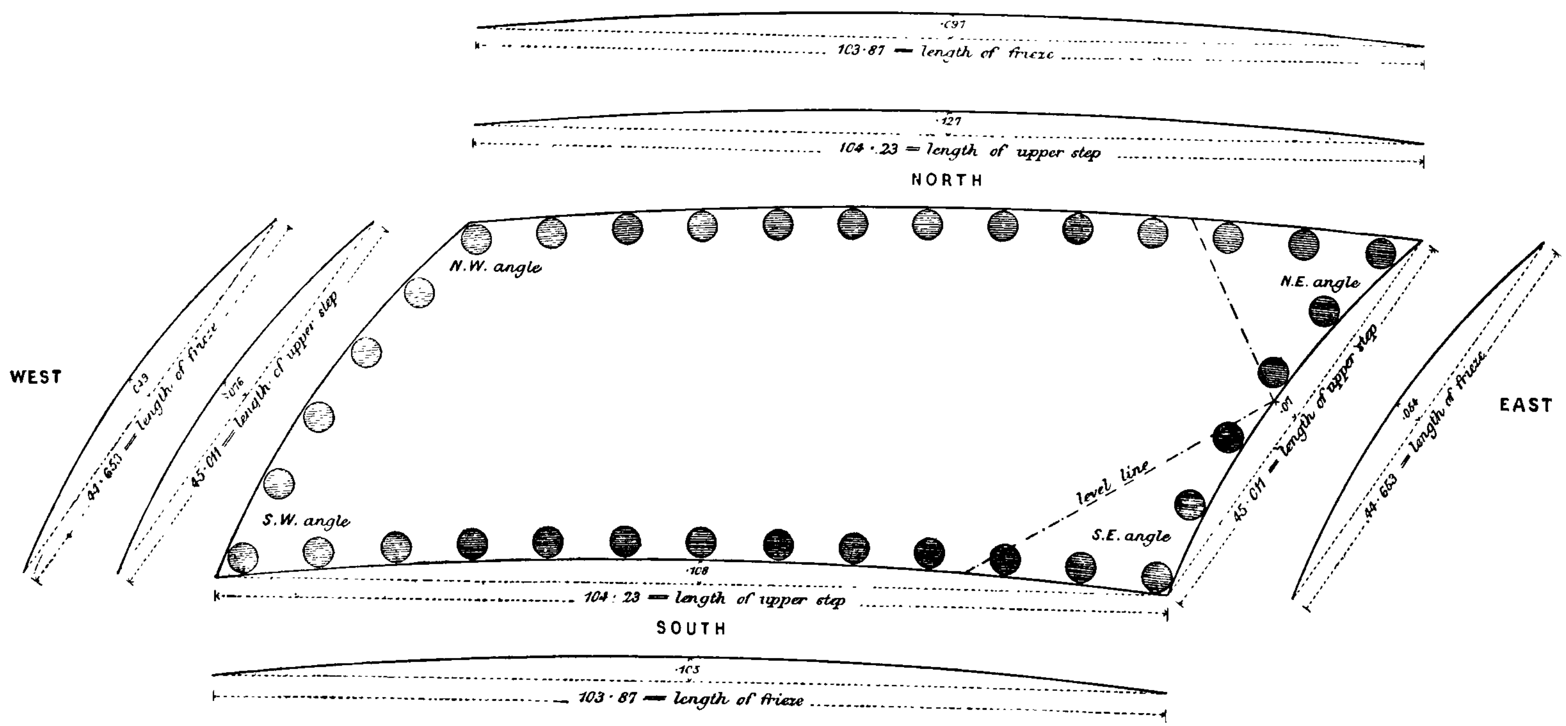



Fig. 7. Curves of the Theseum at Athens. From Pennethorne, Figure 3, Plate III, Part III.

Showing his method of representing the Greek curvature by exaggerated drawing. The measurements are borrowed from Penrose.

rods are liable to a variation at least as great as this, from changes in the moisture of the atmosphere.

On this subject Mr. Penrose also says elsewhere (p. 10):

It is only in a building of the character of the Parthenon, where the excellency of the workmanship is so remarkable, and the destruction from weather so trifling, that measurements can be determined with the minuteness of those laid down in this and most of the following engravings. In the measurements of modern or even Roman buildings, an attempt to obtain the original measurements of considerable distances to the thousandth part of a foot would be fallacious; but in a building of the best Greek workmanship it can be done satisfactorily, if proper care be taken to select such parts of the surface for measurement as have been least exposed to the action of weather; for, owing to the perfect jointing of the stones (the ἁρμονία of Pausanias, or the ἅρμος of the Erechtheum inscription), the errors occasioned by any small shifts, which have arisen from earthquakes, or the violence of human agency, can be corrected most satisfactorily.

To illustrate the refinement of masonry jointing, Mr. Penrose mentions (p. 24) the observation of Stuart that the stones of the steps under the columns of the Parthenon have actually grown together: "On breaking off parts of two stones at the joints, he found them as firmly united as though they had never been separate." This is farther explained as due to the molecular attraction of two surfaces ground together to a very fine finish, on the principle which explains why two panes of glass may adhere to one another. For further details of the methods by which this wonderfully fine fitting and jointing were obtained, the quoted work is the standard authority.

THE great astonishment of modern architects and of modern antiquarians when the purposed irregularities of Greek temple architecture were brought to light is illustrated by the long-continued incredulity with which the publications and measurements of Hoffer, and even those of Penrose, were received, and is attributable to several causes.

First, the Athenian temples had been subjected to careful examination and supposedly accurate surveys since the middle of the eighteenth century by Stuart and Revett,[a] and then by the architects who continued their work, but the horizontal curves were not observed until more than three quarters of a century later, and even the leaning columns were not observed until 1829, when they were announced by Donaldson.

Second, the apparently symmetrical form of the Greek temple type

[a] See especially *The Antiquities of Athens*, by Stuart and Revett, four folio volumes, new edition, London, Priestley and Weale, 1825–30. Stuart and Revett sailed from Venice for Greece in 1750, and returned to England in 1755. The first volume of their work was published in 1767. The fourth volume did not appear until 1816. Meantime, and after the publication of the first vol-

favored the belief that absolute symmetry of details was a natural and necessary counterpart of the general symmetry of plan and form.

Third, the methods and practice of modern architectural design had always assumed geometrical regularity and mathematical accuracy to be the necessary and natural conditions of all "correct" architecture.

For these reasons the discovery of purposed deflections from straight lines, and of other purposed departures from strictly symmetrical arrangements, in the Greek temples was a great surprise to modern antiquarians and to modern architects. The distinguished German antiquarian Bötticher (1806–89) attempted to discredit the curvatures as an intentional refinement by the theory that they were due to settlement at the angles.[a] His theory was decisively overthrown by an examination of the Parthenon foundations which was made by Ziller.[b] The foundation curve of the front of the temple at Corinth was *also subsequently shown by Dörpfeld to have been cut in the solid rock.*[c]

A curious and interesting survival of the period of incredulity is found in a recent work by the able and highly distinguished architectural historian Josef Durm.[d] An earlier special publication by Durm to the same general effect[e] was decisively controverted by A. Thiersch in the same journal for 1873 in a very remarkable article to be again referred to.[f]

As regards the belated scepticism of Professor Durm in the matter of the curves, it may be said that the conclusive proofs of their constructive purpose were already carefully furnished by Hoffer and repeated by Penrose. Two of these proofs are decisive, to say nothing of many others.

One proof is that, as the platform rises toward the centre of each side, the columns resting on the platform would naturally be tipped sideways toward the angles by standing on a sloping surface if the curve were accidental. That the columns actually lean against the downward direction of the slope is due to the fact that the under surface of the lower drum of each column is ground at an angle to overcome the effect of the rising slope. The measurements show that the side of such a drum which

ume, the later volumes were edited or wholly prepared by the most distinguished English architects of the given dates, but the names of Stuart and Revett continued to head the title-page. The fourth volume (1830 edition) adds to the general title: "and other places in Greece."

[a] *Bericht über die Untersuchungen auf der Akropolis von Athen.* Berlin, Ernst und Korn, 1863.

[b] *Ueber die ursprüngliche Existenz der Curvaturen des Parthenons,* in Erbkam's *Zeitschrift für Bauwesen,* 1871, Vol. XXI, p. 470.

[c] *Mittheilungen des K. D. Archäologischen Instituts* (Athens, 1886–7), pp. 297–308.

[d] See his *Baukunst der Griechen* (3d edition, Leipzig, Alfred Kröner Verlag, 1910), pp. 120–134.

[e] *Reisebericht aus Attika,* in the *Zeitschrift für Bauwesen,* 1871, Vol. XXI, p. 470.

[f] *Optische Täuschungen auf dem Gebiete der Architektur,* pp. 9–38. Prof. Dr. August Thiersch (born 1843) is professor of architecture in the Royal Bavarian Technical High School at Munich.

Fig. 8. Curves of the Platform, East Front of the Parthenon.

From a photograph belonging to the Architectural School of Columbia University.

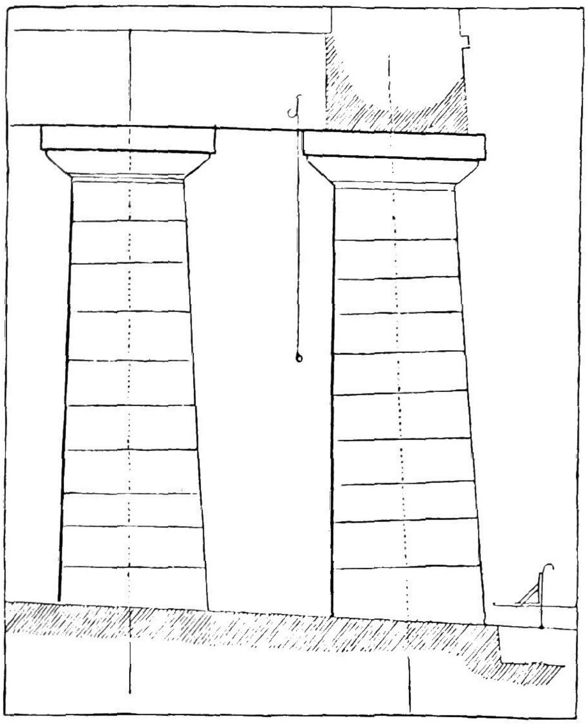


Fig. 9. Exaggerated Drawing of the Setting of the Shafts and of the Shapes of the lower and upper Drums of the Shafts, as related to Curvatures in the Stylobate and Architrave. From Penrose, Fig. 3, p. 36.

faces toward the centre is shorter than the side which faces toward the angle. Corresponding arrangements are found in the uppermost drums of the shafts, where the sides of the drums facing the centre are higher than the sides facing the angles: a necessary accommodation to the rising slope of the architrave.

Another conclusive proof is found in the joints of the platform steps, *which are perpendicular,*[a] whereas the blocks themselves are sloping.[b] If settlement or pressure had caused the curve, the joints would lean outward.

It would appear that the directions given by Vitruvius, when related to the undoubted and visible existence of the curvature, should be sufficient to convince any sceptic, aside from the conclusive proofs just quoted and others too numerous to mention. (See Fig. 9, p. 17, from Penrose, Fig. 3, p. 36.) The objections as to technical constructive points which have been marshalled by Durm were carefully controverted by Thiersch, as just noted. The passage from Vitruvius is quoted

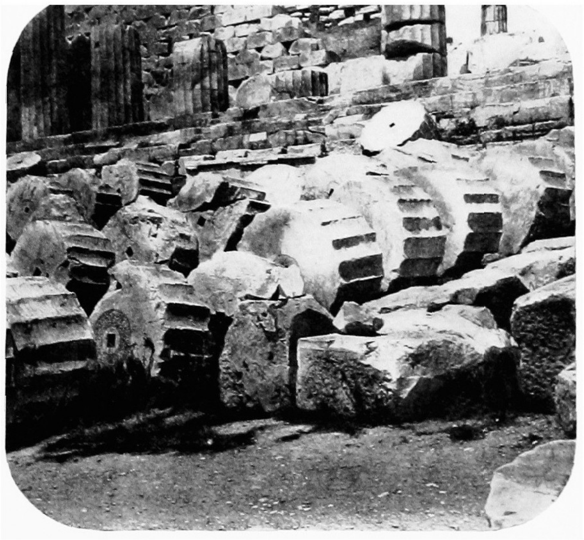


Fig. 10. Drums of Fallen Columns of the Parthenon.

[a] Hoffer, *Wiener Bauzeitung,* 1838, p. 380.

[b] The Greek curves really consist of a number of bends in straight lines, each block having a straight upper and under surface, with the end surfaces so cut obliquely as to fit accurately with the ends of the adjacent blocks. If Plates X and XI of the *Principles of Athenian Architecture* be examined, it will be found that the curves of the stylobate at the ends of the Parthenon are constructed in four straight lines, with three bends, on each side of a central bend. The curves of the corresponding architraves are constructed in four straight lines, with three bends, on each side of a central straight line. The optical effect is that of a regular curve, but that is not the construction. Fig. 5, p. 7, reproduces Penrose's Plate XI.

in Appendix[5] to this chapter. It would be wholly incredible that formal directions for the construction of horizontal curvature should have been given by an ancient architect, unless an actual and traditional practice of the given refinement had existed.

The following remarks of Mr. Penrose, at p. 28 of his work, as to the question of purposed construction, also have great interest in this connection:

> That all these cases of curvature can have arisen from accident or carelessness is utterly impossible. In that case the lines would be broken and uneven, instead of the beautifully regular curves which we generally find; still less would it be found, in every case of curvature in the front of the temple, that the very part which is raised most above the level—namely, the centre of the front—is that where the greatest weight (that of the pediment) presses upon the stylobate; which reason, coupled with the provision of the *scamilli impares*,[a] leaves no doubt on the subject. Did it seem necessary to carry this argument farther, a direct proof could be obtained from the measurement of the cracks in the architrave stones (given in Plates VII and VIII), a conclusive test (especially in a Greek building of the best time) in discriminating between a real or accidental increment of curvature.

As bearing on the scepticism of Professor Durm; it may be added that very careful observations of the horizontal curves of the temple of Egesta in Sicily have been summed up as follows by the most recent German surveyors of that temple, who are notably careful and conservative in all their observations and conclusions: "Moreover, aside from the removal of a few blocks, the building is in perfect condition. The joints fit accurately, and it would hardly be possible to endeavor to explain this curvature as a later distortion of the temple."[b] The same authors have also recorded their reasons for considering the curves in elevation of the temple of Poseidon at Pæstum to be constructive, and conclude with the words: "We . . . therefore believe in an original curvature of the stylobate."[c]

An account of the various theories which have been advanced to explain the horizontal curvature of the Greek temples will be offered in the next chapter. Generally speaking, the subject has been much neglected. A merely summary notice is the rule, even in books of considerable importance. In the mentions which have been made in recent popular compendiums, the view has been also almost universal that the Greek re-

[a] By which Mr. Penrose means the lower drums of the columns, which are of unequal height on opposite sides, as just explained.

[b] "Dabei ist der Bau, wenn man von der Beraubung einzelner Partien absieht, tadellos im Stande; die Fugen schliessen mit Genauigkeit, und es würde kaum angehen, hier die Erklärung dieser Curve in einer späteren Deformation des Tempels suchen zu wollen." Koldewey und Puchstein, *Die Griechischen Tempel in Unteritalien und Sicilien.* Berlin, A. Asher & Co., 1899, Behrend & Co., Successors.

[c] Pages 25, 26.

finements were designed as optical corrections of optical effects of irregularity. In other words, *geometrical effect* is supposed to have been sought by departure from *geometrical fact.* For instance, the upward horizontal curvature has been widely explained as the correction of an optical effect of downward curvature. In other words, the horizontal lines of Greek temples are widely said to have been *actually curved* in order that they might appear to be *actually straight.*

In this chapter it need only be said that this general impression is wholly erroneous, and that the proofs of its error have been published in such form that no answer is possible and that none has been attempted.[a] These proofs will be repeated in the next chapter.

Fig. 11. A Drum of the Parthenon.

In spite of the neglect with which the Greek refinements have been treated, and of the errors about them which have been widely circulated, there is no doubt that in some cases (*a*) they were modulations designed to please the eye by avoiding the inartistic effects which attend formal monotony in art;[b] that in other cases (*b*) they were modulations intended to suggest and accent desirable effects; and that in still other cases (*c*) they were modulations intended to avoid unpleasant effects, such modulations being based on the knowledge that mathematical accuracy as to correspondence in detail is in itself undesirable and is an inconceivable aim in good art.

An example of the (*a*) type of modulation is the horizontal curvature.[c] An example of the (*b*) type of modulation is the convergence and inward leaning of the main perpendicular lines, which gives an effect of solidity

[a] Goodyear, in *American Journal of Archæology,* second series, Vol. XI (1907), No. 2: "The discovery, by Professor Gustavo Giovannoni, of Curves in Plan Concave to the Exterior in the Façade of the Temple at Cori." This article also appeared in the *Architectural Record* for June, 1907. The measurements for the temple of Cori, quoted in these articles as obtained from Professor Giovannoni, were subsequently revised by his more accurate surveys, which will appear in the next chapter.

[b] Compare the article "Refinements in Design" in the *Dictionary of Architecture,* edited by Dr. Russell Sturgis (Macmillan), and also the quotation from this article in Chapter III, p. 95.

[c] Compare the quoted article in the Sturgis-Macmillan *Dictionary,* and extract from this article in Chapter III, p. 95.

and strength.[a] An example of the (*c*) type of modulation is the diminished spacing of the angle columns and the attendant variations in the metope widths. These were designed to avoid the unpleasant effect which would result from placing a triglyph directly over the centre of the angle column. The triglyph would in that case be some distance removed from the angle of the temple frieze, where, for good effect, it ought to be.[b]

To the foregoing preliminary and summary account of the Greek architectural refinements, the following conclusions and statements may be added, some of them being, by implication, involved in what precedes.

First, all accurate knowledge of Greek temple architecture is later than 1838, even when the questions of fact, as distinct from theoretic explanations, are alone considered.

Second, a satisfactory philosophy of the Greek refinements exists, but has not yet found its way into the popular compendious books on the subject. For instance, the widely quoted explanation that the Greek curvatures were intended to correct an optical effect of downward sagging is wholly disproved by Professor Giovannoni's discovery at Cori, and by my own observations, at Pæstum, of curves concave to the exterior which produce an optical effect of downward sagging. This point will be developed in the second chapter.

Third, the modern copies of the Greek temples are inadequate and ineffective replicas of the originals, and the most renowned modern copies were made before the most important features of these temples were known to exist. Supposing that it had been possible to reproduce these refinements, the Greek Revival (so called), in which the original Greek monuments were directly copied, dated from the last half of the eighteenth century, before the refinements were discovered, and this revival had mainly come to an end before their existence was widely known. Soufflot's façade of the Pantheon at Paris, which is known as the first modern portico in imitation of the Greek originals, dates from 1764, and the Greek Revival

[a] See also Chapter V, p. 144.

[b] The best and perhaps the only complete and detailed explanation of the motives of these arrangements in the Parthenon was published in 1879 by Dr. Guido Hauck, then professor of descriptive geometry and of graphostatics in the Royal Technical High School of Berlin. See pp. 130–133 of his *Subjektive Perspektive und die Horizontalen Curvaturen des Dorischen Styls.* Stuttgart, Konrad Wittwer, 1879. For Hauck's explanation of the variations in the Parthenon metopes, see Chapter VI, p. 201. For the general subject of the spacial contraction of Greek temple columns at the angles, as connected with the problem of the angle triglyph, see the same chapter, pp. 186–188, 199, 200.

Dr. Hauck was born in 1845 and died in 1905. Among his other works are *Lehrbuch der Stereometrie* (1872), *Stellung der Mathematik zur Kunst* (1880), *Malerische Perspektive* (1882), and *Uebungsstoff für den praktischen Unterricht in der Projektionslehre* (1891).

produced its most important monuments, such as the Madeleine at Paris, in the late eighteenth and early nineteenth century. Since the date of Penrose's publication in 1851, few buildings of serious importance have been attempted in Greek temple style.

Fourth, the only mention of the Greek horizontal curvature in extant ancient classic literature, which was made by Vitruvius, a Roman architect and author of the early Empire, was overlooked until 1837, although the book in which this notice appears had been carefully, and even reverently, studied since the beginning of the sixteenth century.

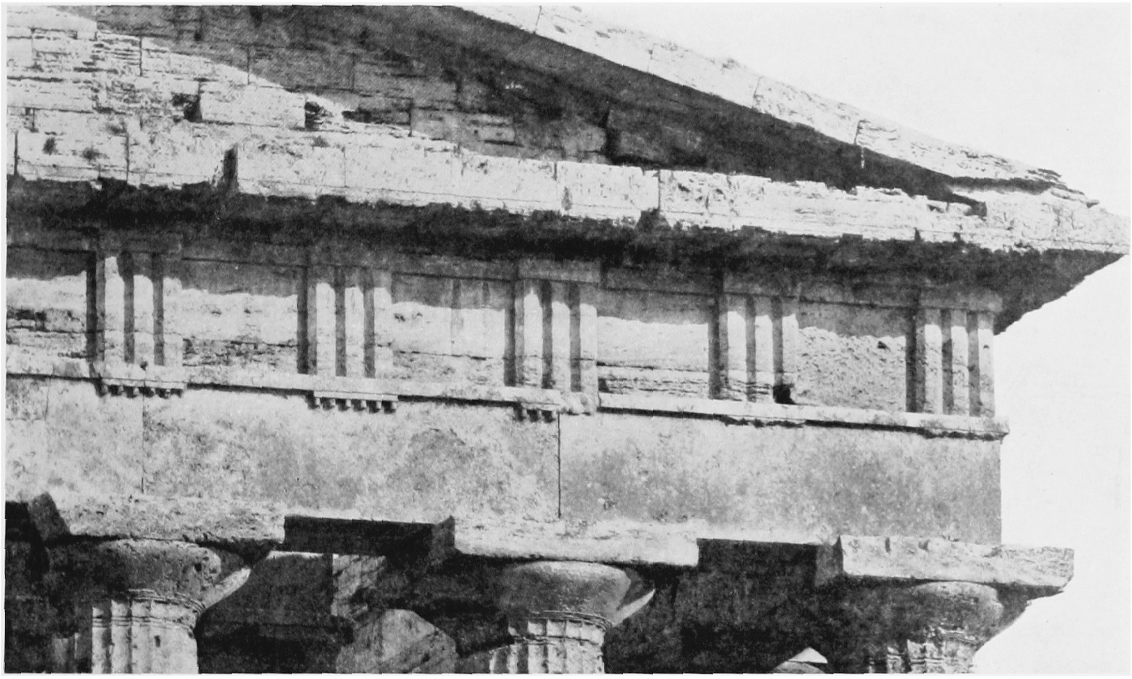


Fig. 12. Entablature and Pediment of the so-called Temple of Poseidon at Pæstum.
To illustrate the decentring of the angle triglyph, as related to the angle column.

As an illustration of this fact it may be mentioned that the English translation of Vitruvius, made by the celebrated architect Wilkins and published in 1812, even contains a foot-note to the passage relating to the curves, which states that they were probably never actually employed. In other words, the statement of Vitruvius was considered so improbable by Wilkins and by his contemporaries that he did not even apply the test of observation to the monuments. He assumed that the facts would have been previously noticed if they had existed in the extant ruins. The foot-note by Wilkins reads as follows: "This great refinement, suggested by physical knowledge, does not appear to have entered into the execution of the works of the ancients."[a]

Fifth, even the entasis of the columns had passed unnoticed in the Greek examples until 1810, and was then observed for the first time by Cockerell.[b] Penrose is the authority for this astonishing fact, which is the more remarkable because the Roman entasis, which was derived from the Greek, had been copied by the Renaissance architects and their successors down to our own time and since the fifteenth century. Palladio's buildings are a notable and sufficient instance. The related passage from Penrose is worth quoting here:

Fig. 13. The Theseum at Athens, about 470 B.C.

> Again, when we consider the long interval which elapsed between the visit of Stuart and that of Professor Cockerell, *by whom the entasis of the columns of the Parthenon was discovered,* and that it was reserved for Professor Donaldson to establish the Vitruvian inclination of the columns, we need not be greatly surprised that this curvature in the horizontal lines was not found out until a later period. (Pages 23, 24.)

Penrose adds, in a foot-note, that the dates mentioned are 1755 for Stuart's visit, 1810 for Cockerell's discovery of the entasis, and 1829 (*circ.*) for Donaldson's discovery of the leaning columns. Hoffer says, in the "Wiener Bauzeitung," that the Greek entasis was discovered by the English architect Jenkins, thus corroborating the point that it is a modern discovery.

The truth appears to be that the first measurements, but not the first observations, of the entasis were those published by William Jenkins in the fourth volume of Stuart and Revett's "Antiquities of Athens," 1830. It is also there mentioned that the Greek entasis "had escaped even the minute and exact attention of Stuart and Revett." Cockerell's discovery of the Greek entasis in 1810 is also mentioned by Thiersch in his essay quoted on

[a] See p. 21 of *The Civil Architecture of Vitruvius. Comprising those Books of the Author which relate to the Public and Private Edifices of the Ancients.* Translated by William Wilkins, M.A., F.A.S., late Fellow of Gonville and Caius College, Cambridge; author of *The Antiquities of Magna Græcia.* Illustrated by numerous engravings. With an Introduction containing an Historical View of the Rise and Progress of Architecture Amongst the Greeks. London, printed by Thomas Davison, Whitefriars, for Longman, Hurst, Rees, Orme, & Brown, Paternoster Row. 1812.

[b] For the nature and explanation of the Greek columnar entasis, see Chapter III, pp. 99–102.

p. 14. Michaelis, in "Der Parthenon" (1871), attributes the discovery of the entasis to Cockerell, but in his later "Century of Archæological Discovery"[a] he says that it "had already been observed by Wilkins." This would still place the first observation inside the limits of the nineteenth century.

ALTHOUGH a comprehensive and satisfactory philosophy of ancient architectural horizontal curvatures ought evidently to include the oldest which are known, and these were also the earliest as to date of modern discovery, it is, notwithstanding, true that the discovery of the horizontal curvature in Egyptian temples was not published to the world until 1878, although it was made in 1833, and although it was undoubtedly from Egyptian examples, or Egyptian instruction, that the idea of curvature was suggested to the Greeks.

The following are the facts relating to this discovery of the Egyptian curvature. In the winter of 1833, Pennethorne observed curves in plan[b] convex to the centre of the court in the second temple court at Medinet Habou (Thebes). He had then already been in Athens in 1832 without having noticed the Greek curves in elevation. In 1835 he made a second visit to Athens, and again without observing the curves. It was not until the period between 1835 and 1837 that the perusal of the passage in Vitruvius determined Pennethorne to make a third visit to Athens. In his own words (not published until 1878): "I returned to Athens in 1837, . . . fully expecting to find confirmation of what Vitruvius so clearly stated."[c]

Thus the discovery was made in Athens *after the observation of the curves in Egypt;* but notwithstanding this sequence of the actual events, the existence of the Egyptian curves *remained unknown to the world until 1878.* Not until then did Pennethorne make his publication on "The Geometry and Optics of the Ancients."

The explanation of this tardiness in publication is that this great pioneer could not awaken sufficient interest in his discovery to enable him to prosecute his research. So utterly hopeless had this ambition become that he did not even know, until the year 1860, that the Greek refinements had been measured by Penrose in 1845–6, and published in 1851. On this head we may quote from Pennethorne's preface published in 1878. After mentioning various deficiencies in his observations which it was necessary to make good before publication could be undertaken, the preface continues:

[a] Murray, 1908, tr. by Bettina Kahnweiler.

[b] *i.e.*, curves in horizontal planes, as distinct from the rising curves in vertical planes (curves in elevation), such as are best known in the Parthenon.

[c] Page 81 of his book.

I therefore laid the work aside, *not intending to resume the subject,*[a] feeling that did not possess sufficient data to enable me to complete it, nor, at the time, *the mea of making any further researches,* and that it was not an investigation likely to recei the support either of the English government or of any private society, so I becan engaged for some years in agricultural pursuits. In the year 1860 an illness oblige

Fig. 14. Curves of the Parthenon, Entablature of the Inner Portico, West Front.
Commercial photograph.

me to relinquish agriculture and forced me into great retirement, when, looking over Mr. Penrose's work published by the Society of Dilettanti, and Mons. Beulé's work "L'Acropole d'Athènes," I found that nearly all the information required had been collected between the years 1846 and 1854. . . .

Thus, on account of the belated announcement of the discovery of curves in Egypt, the various theories which have been advanced by optical

[a] Italics by W. H. G.

Fig. 15. Pylon at Medinet Habou. Entrance to second Temple Court.

experts in explanation of the ancient curves have been based on wholly insufficient knowledge of the facts involved. No serious consideration by any optical expert of the optical questions involved in this subject has appeared since 1879, when Dr. Guido Hauck published his remarkable brochure on "Subjective Perspective and the Horizontal Curves of the Doric Style."[a] As the work of Pennethorne had preceded this publication by only a year or less, Hauck was not aware of its existence, and consequently did not know of the Egyptian curves in plan. His explanations were therefore confined to the Greek curves in elevation.

It results that Hauck's own optical theories, as well as those (to be subsequently mentioned) of his distinguished predecessors Hoffer, Penrose, and Thiersch, do not cover extremely important facts. Hauck's theory was even based on the supposition, as suggested by the title of his essay, that the curvatures were not found in the Ionic style, and his highly ingenious and otherwise interesting explanation is limited to arrangements which are found only in the Doric order, whereas one Ionic temple with curvatures has subsequently been found at Pergamus,[b] and another has been found at Messa on the island of Lesbos.[c] Moreover, even the directions of Vitruvius relate to Ionic temples. The theory of Penrose, on the other hand, moves from the gables of the Greek temple, and the Egyptian temple court had no gables.

The last notable point to be made in this preliminary account of the subject is that the existence of horizontal curvatures in Roman temples *was unknown to the world until 1891,* although our only literary record for the ancient curvatures is found in a Roman author.[d] Additional mention of

[a] See foot-note, p. 20. See also pp. 56, 62–64, and Appendix 5, Chapter II.

[b] See *Altertümer von Pergamon,* Vol. IV, Plate XXXI (Berlin, Spemann, 1896), and Fig. 72, p. 123, of this volume.

[c] See p. 125.

[d] Goodyear, in the *Architectural Record,* Vol. VI, No. 4 (1895); in the *Smithsonian Reports* (1896); and in the *American Journal of Archæology,* Vol. X, No. 1 (1895): "A Discovery of Horizontal Curves in the Maison Carrée at Nimes." For Professor Gustavo Giovannoni's discovery, in

these curves of the Roman period will be found in the next chapter. For the moment the point in view is only to emphasise the very recent dates at which these various revolutionary observations have been made, and the consequent wide diffusion of certain erroneous views on the general subject, which will be considered in the next chapter.

1904, at Cori, see Giovannoni, in the *Mittheilungen des K. D. Archæologischen Instituts* (Rome, 1908), Bd. XXIII, pp. 109–130: "La Curvatura delle Linee nel Tempio d'Ercole a Cori."

Fig. 16. The Propylæa, Athenian Acropolis.

# APPENDIX. CHAPTER I

[1] The following table of measurements, in feet and foot decimals, is taken from the *Principles of Athenian Architecture,* p. 27:

| | Actual length of the front or flank | Actual rise above a straight line joining the extremities | Proportional rise corresponding to a length of 100 feet |
|---|---|---|---|
| Jupiter Olympius[a] | | | |
| Flank . . . . . . . . . . . | 354.2 | .25 nearly | .07 |
| Sub-basement of the Parthenon[b] | | | |
| Front . . . . . . . . . . . | 104.2 | .150 | .145 |
| Flank . . . . . . . . . . . | 221. | .233 | .105 |
| Theseum | | | |
| Front . . . . . . . . . . . | 45. | .063 | .140 |
| Flank . . . . . . . . . . . | 104.2 | .101 | .097 |
| Parthenon | | | |
| Front . . . . . . . . . . . | 101.3 | $.228 = \text{flank} \times \frac{1}{1000}$ | $.225 = \frac{3}{2}.145$ } very nearly |
| Flank . . . . . . . . . . . | 228.1 | .335 | $.156 = \frac{3}{2}.105$ } very nearly |
| Entablature from eastern front | 100.2 | $.171 = \frac{3}{4}.228$ | .171 |
| Do. on flanks, restored . . . | 227. | .307 | .135 |
| Propylæa | | | |
| Entablature from eastern portico . . . . . . . . | 68.1 | .119 | .175 |

This table, which is copied as printed, omits mention of the entablatures of the Theseum, but the measures for these are elsewhere quoted (p. 73) as being "about one-fourth less than that of the stylobates in the fronts, and one-tenth part less in the flanks." This omission from the table is apparently due to the wish to include in it only absolutely authentic amounts of original curvature, and to the belief of Mr. Penrose, as elsewhere stated, that the slightly diminished curvature in the entablatures of the Theseum is the result of accidental flattening.

[a] The orthography of Penrose is naturally followed in all quotations from his work. From personal preference of the Author, and also in order to avoid diverse spellings of the same temple names, the same orthography has also usually been followed elsewhere, as regards the Athenian ruins, as, for instance, in Theseum, Erechtheum, etc.

[b] This is the substructure of the earlier Parthenon, which was destroyed by the Persians.

There is no curvature in the stylobate of the Propylæa (Penrose, p. 27).

The above table shows that the increments of curvature are relatively less, as related to a given length, on the flanks than they are on the fronts of the quoted monuments. This is stated to be the case in all known monuments (p. 105). The reason, obviously, is the desire to avoid any great excess in the difference of level between the centres of the sides and the centres of the fronts.

As regards the dates of the monuments mentioned in this table, the first two belong to the sixth century B.C., and the others to the fifth century. The platform of the temple of Olympian Zeus dates from the period of Pisistratus, although the colonnades were first begun in the Macedonian period and were not completed until the time of Hadrian. The existing columns (Fig. 48, p. 80) probably belong to the periods of Antiochus Epiphanes, Augustus, and Hadrian.

[2] The only photographs of ancient curvature so far known to periodical or book publication, by means of half-tone or photogravure, are three in number, aside from publications by the writer. These are the Ionic temple at Pergamus (Appendix[9], Chapter IV), the concave curve at Cori (foot-note[a], p. 47), and the south flank of the stylobate of the temple at Egesta, published by Sturgis in his *History of Architecture*, Vol. I, p. 154. This last illustration represents a print from the Brooklyn Institute Museum series of 1895.

Two of the four photographic illustrations of the Parthenon curves which appear in this volume, viz., Fig. 50, p. 85, and Fig. 51, p. 89, are borrowed from the views of the Athenian ruins which were taken by Mr. W. J. Stillman and published as photogravures without text (aside from the captions of the photographs).[a]

The numerous photographs of curvature from Pæstum, Girgenti, and Egesta which are published in this volume belong to a series which is believed to be the only one extant for the given temples in this particular. These were taken in 1895, on behalf of the Brooklyn Institute Museum and under the direction of the writer, and were made by Mr. John W. McKecknie, now an architect in Kansas City. Mr. McKecknie was an accomplished professional surveyor as well as an expert photographer. Many of his photographs were taken "in parallel perspective," *i.e.*, with the camera facing the centre of the given flank or front exactly at a right angle. To obtain such a view the use of a compass is necessary. In Mr. McKecknie's photographs straight lines have been generally ruled on the negative, in order to make the curve more easily visible by this contrast.

The use of a perfectly rectilinear lens is naturally indispensable when architectural curves are to be photographed.

[3] It is also stated by Penrose (p. 37) that "the sides of the beams of the ceiling, and almost all the other flat surfaces, are inclined backwards or forwards, according

[a] Mr. W. J. Stillman was American consul in Crete (1865–68), and for many years an archæological correspondent of the London *Times* and of the New York *Nation*. His photographs were published in photogravure under the following title: *The Acropolis of Athens. Illustrated picturesquely and architecturally in photography*. By William J. Stillman. Printed by the Autotype Company, London. F. S. Ellis, 33 King St., Covent Garden, 1870.

to the situations where they are placed; and generally we may remark that *perpendicular faces are the exception and not the rule.*"[a]

As regards the measurements (*in foot decimals*) which follow here, they represent observations of the Parthenon and they vary frequently, and sometimes considerably, in other monuments, but it is mentioned by Penrose (p. 37) that "all the inclinations which have been found in the Parthenon are found in similar parts of the Propylæa and generally also in the Theseum."

The columns of the Parthenon are inclined inward 0.228, or about 2¾ inches, in a total height of 34.26 feet. This inclination is in the proportion of 1 to 150. The in-

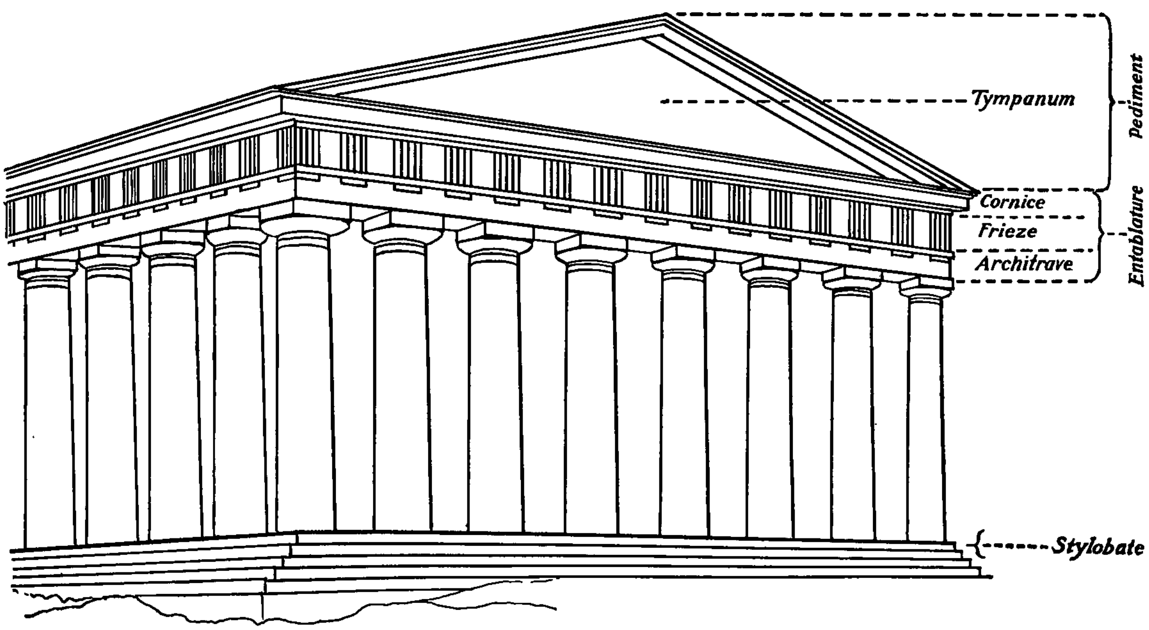



Fig. 17. Drawing showing the Principal Divisions of a Greek Temple.

ward inclination of the side walls is greater, being in the relation of 1 to 80. The antæ or pilasters at the ends of the side walls lean outward, 1 in 80. The inward inclination of the architrave and frieze is 1 in 80. The inward inclination of the steps of the platform is 1 in 250. In the face of the cornice (or corona) the forward inclination is 1 in 100. The acroteria and antefixes lean forward $1/20$ of their height. The front vertical faces of the abaci lean forward 0.008, or about $1/16$ inch, in a thickness of 1.149 feet. The inclination of the door jambs, which converge slightly in the rising direction, is 0.114 in a height of 33 feet (p. 46). Most of the foregoing measurements are found on p. 37 of the *Principles of Athenian Architecture.* The inclinations of the abaci are described at p. 15, but the measurements are only found on Plate VII.

The index of the quoted work gives references, under "Inclinations," for the above facts and also for various deviations from them in other monuments. The explana-

[a] Throughout this work, the passages in quotations which are emphasised by italics are so marked by the Author of this volume, unless the contrary is stated.

tions of these inclinations are the same in some instances and they vary in others, as subsequently described in text of this work, especially in Chapter V, pp. 144–149.

[4] As shown by the illustrative Figure 17, the stylobate is the platform of the temple. In strictly technical use the term is limited to the platform surface masonry, thus including its upper step, the lower steps and connected substructure of the remainder of the platform being known as the stereobate. The word stylobate is, however, used in this volume to include the entire platform construction, as the curves, when they occur, invariably begin at the foundations.

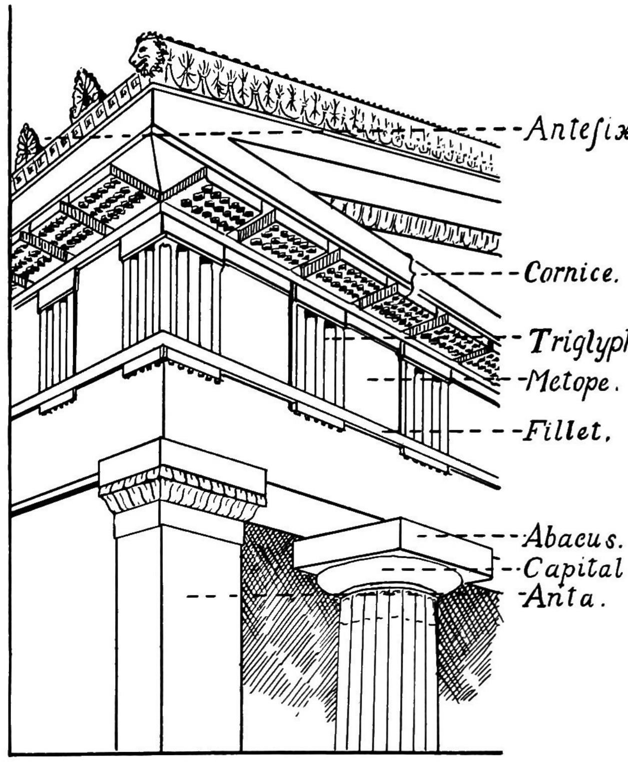



Fig. 18. Drawing showing the Principal Details of a Greek Temple.

The abaci (Fig. 18) are the rectangular flat blocks which intervene between the capitals of the colonnade and the entablature. They are needed to increase the supporting surface beneath its horizontal members.

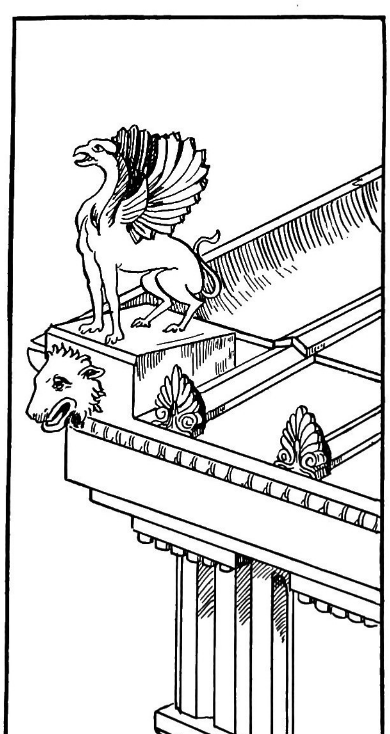


Fig. 19. An angle Acroterium.

The entablature (Fig. 17) embraces all the horizontal members above the colonnade, of which there are three. These are known as the architrave (or epistyle), which rests on the abaci; the frieze, which rests on the architrave; and the cornice.

The frieze of the Doric temple is decorated by the triglyphs (Fig. 18), literally "three grooves"; and, in spite of other explanations which have frequently been offered, it is probable that the triglyphs are copied from a similar ornament in Egyptian architecture, which is frequently found on the corresponding member of the Egyptian entablature, and which actually did consist of three upright grooves decorated in color. Greek ornament frequently projected, in relief, modification of motives which the Egyptians had used in flat color or incised, and the Greek Doric triglyph thus consists of three projecting upright bands, separated by two grooves, and wi.h an additional half groove on each outer side. The form of the triglyphs is shown in numerous illustrations besides Fig. 18 (see, for example, Fig. 12, p. 21). The number of the triglyphs is always double the number of the columns, and they are arranged alternately over the columns and over the intercolumnar spaces.

The metopes are the spaces between the triglyphs, and were frequently filled by relief sculpture.

The pediment is the low triangular gable which corresponds, on the fronts of the temple, to the sloping sides of the roof. It is coped by a cornice which corresponds in design to that of the entablature below it, with which it is mitred.

As shown by Fig. 19, the roof of the temple was covered by slabs of marble or other stone (or by tiles), and these were supported by timber beams. The joints of these slabs were again covered by roof-shaped ridges, to prevent the infiltration of rain or melting snow between the joints. The ends of these ridges were faced by the antefixes, which were arranged along the edge of the cornice (Figs. 18, 19, and 21).

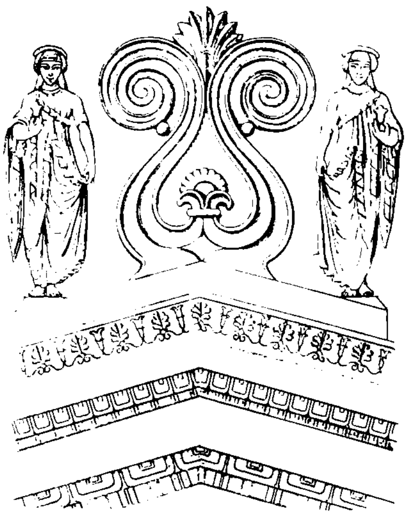


Fig. 20. Acroterium from the Gable Apex of the Temple of Ægina. From a drawing in Stuart and Revett's "Antiquities of Athens."

Ornaments were placed at the angles of the pediment as well as on its apex. These are called acroteria and had a great variety of forms. Two of these are suggested by Figs. 19 and 20.

The function and position of the anta are shown by Fig. 18. It is a pilaster which decorates the end of a wall. In this figure it is part of the front of the building. In the Parthenon and in the other temples illustrated in this volume the location of the antæ is concealed by the front colonnades. The ground-plans will, however, indicate their position; for instance, see Fig. 6, p. 10.

No effort is made to include any terms in these definitions, or in the illustrative figures, which are not called for by the subject-matter of this book. Other terms have been purposely excluded, in order to simplify the figures and the explanations.

With the exception of the Ionic temple at Pergamus (Fig. 72, p. 123), all known instances of Greek curvature occur in peripteral temples, *i.e.*, in those of oblong rectangular plan which were entirely surrounded by a colonnade. Most of the illustrations of this volume represent such temples, and it is the most characteristic Greek type for the more imposing shrines. It must, however, be remembered that there were variations from this employment of the colonnade which were natural to smaller and less pretentious buildings of similar oblong plan, as shown by Fig. 18, and by Fig. 74, p. 130. There were, again, other temples of remarkably irregular plan, such as the Erechtheum (Fig. 71, p. 121).

[5] The passage in Vitruvius is translated from Lib. III, 3, by Wilkins, as follows:[a]

[a] For the title and date of this translation, see foot-note[a], p. 22.

"The stylobate ought not to be constructed upon the horizontal level, but should rise gradually from the ends towards the centre, so as to have there a small addition. The inconvenience which might arise from a stylobate thus constructed may be obviated by means of unequal scamilli.[a] If the line of the stylobate were perfectly horizontal, it would appear like the bed of a channel."[b] Farther on in the same chapter the following passage occurs: "In placing the capitals upon the shafts of the columns, they are not to be arranged so that the abaci may be in the same horizontal level, but must follow the direction of the upper members of the epistylium,[c] which will deviate from the straight line drawn from the extreme point in proportion to the addition given to the centre of the stylobate."

The original passages in Vitruvius are here quoted: "Stylobatam ita oportet exæquari, uti habeat per medium adjectionem per scamillos impares. Si enim ad libellam dirigetur, alveolatus oculo videbitur. . . . Capitulis perfectis, deinde in summis columnarum scapis non ad libellam sed ad æqualem modulum collocatis, uti quæ adjectio in stylobatis facta fuerit, in superioribus membris respondeat symmetria epistyliorum."

It will be noticed that the three words *per scamillos impares* have been translated by Wilkins *by an entire sentence,* viz.: "The inconvenience which might arise from a stylobate thus constructed may be obviated by means of unequal scamilli." From the luminous explanation of this term given in Chapter IV (p. 114), it will appear that a literal translation of *per scamillos impares,* "by means of unequal scamilli," would have given the true sense, which is wholly obscured by this free translation. At the end of the work Vitruvius refers to an illustration as to the arrangement of the *scamilli impares.* This has been lost.

[a] The true explanation of the term "unequal scamilli" was not understood by Penrose, but has been given by Burnouf (see Chapter IV, p. 113).

[b] *i.e.,* it would appear to "dish" downward or to be depressed toward the centre. Compare Chapter II, p. 58.

[c] *i.e.,* of the architrave.

Fig. 21. Antefix from the Parthenon.

# CHAPTER TWO

## ERRONEOUS EXPLANATIONS OF THE GREEK HORIZONTAL CURVATURES AS DESIGNED TO CORRECT AN OPTICAL ILLUSION

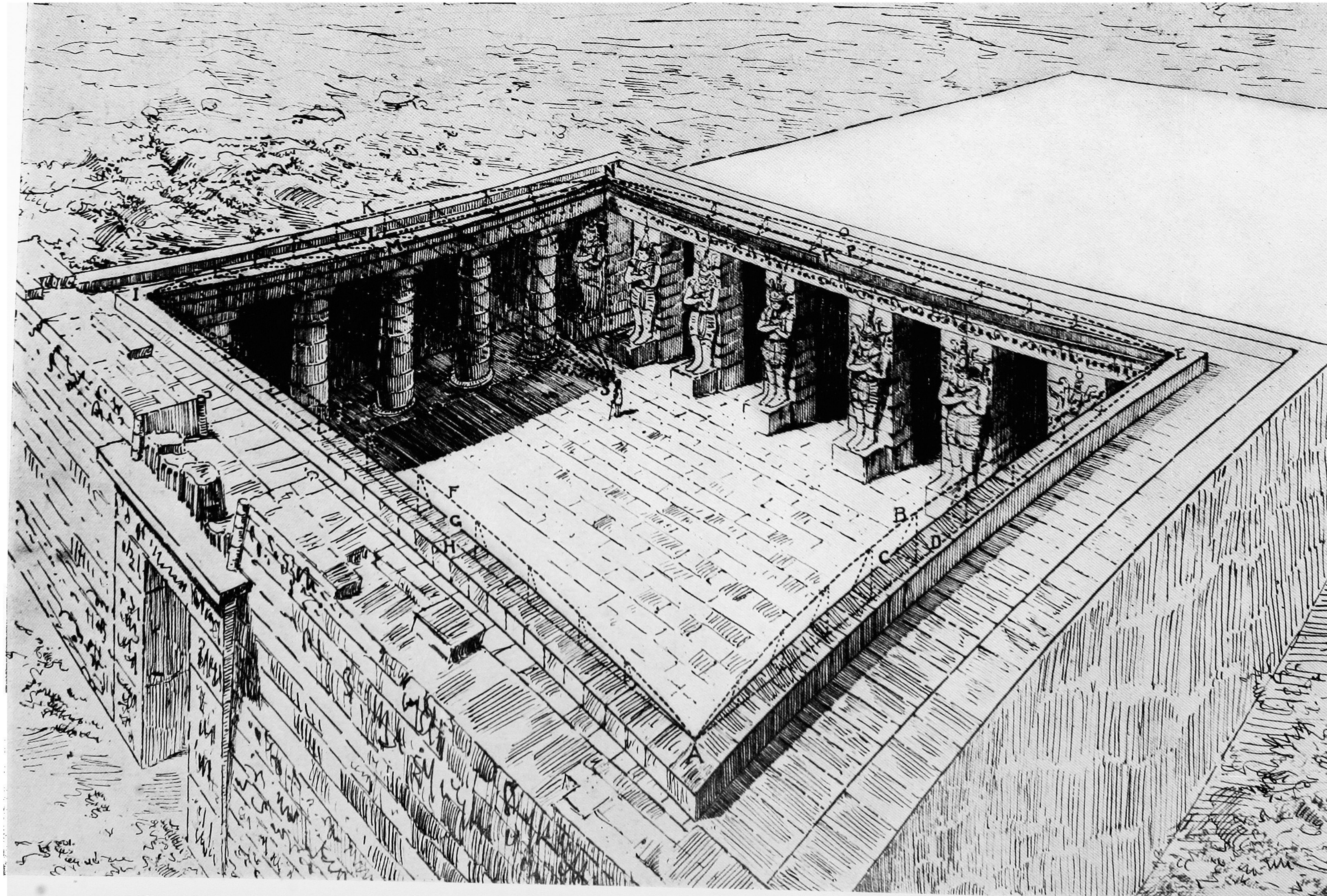



Fig. 22. Curves in Plan of the Second Temple Court at Medinet Habou. Thirteenth Century B.C. Bird's-eye View.
The dotted lines of curvature represent the optical effect from the court interior, as being that of rising curves in elevation. See Appendix[4].

# CHAPTER II

## ERRONEOUS EXPLANATIONS OF THE GREEK HORIZONTAL CURVATURES AS DESIGNED TO CORRECT AN OPTICAL ILLUSION

It has been mentioned in the preceding chapter that the earliest modern observations of architectural horizontal curvature were made in Egypt in 1833, but that, owing to the indifferent or adverse reception of Mr. Pennethorne's discoveries, the existence of these Egyptian curvatures was not published by him, or otherwise made known, until 1878. It may also be said that the existence of Egyptian horizontal curves has been generally unknown, even to the world of special learning in such matters, and even since that relatively recent date.

As a possible explanation it may be said that, aside from the very unusual bulk and great cost of Mr. Pennethorne's "Geometry and Optics of the Ancients," there are portions of it which are very difficult, and not very profitable, reading. This may partly account for the slight attention which has been paid to his observation of curves in plan in the second temple court at Medinet Habou, which takes up a very small part of the book.

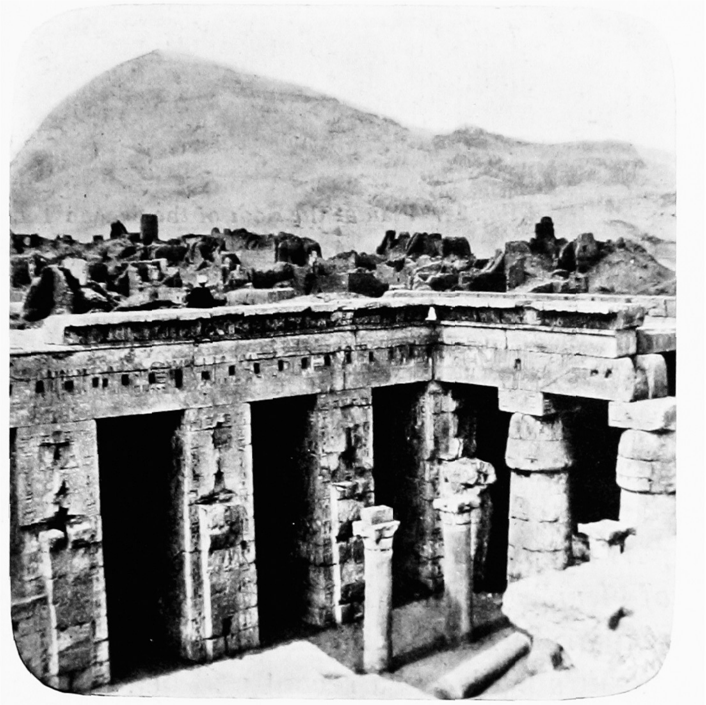


Fig. 23. The Second Temple Court at Medinet Habou.

The amiable nature and great worth of Mr. Pennethorne's character, combined with his remarkable services as a pioneer discoverer (he was also the first to announce the derivation of Greek ornament from the Egyptian,

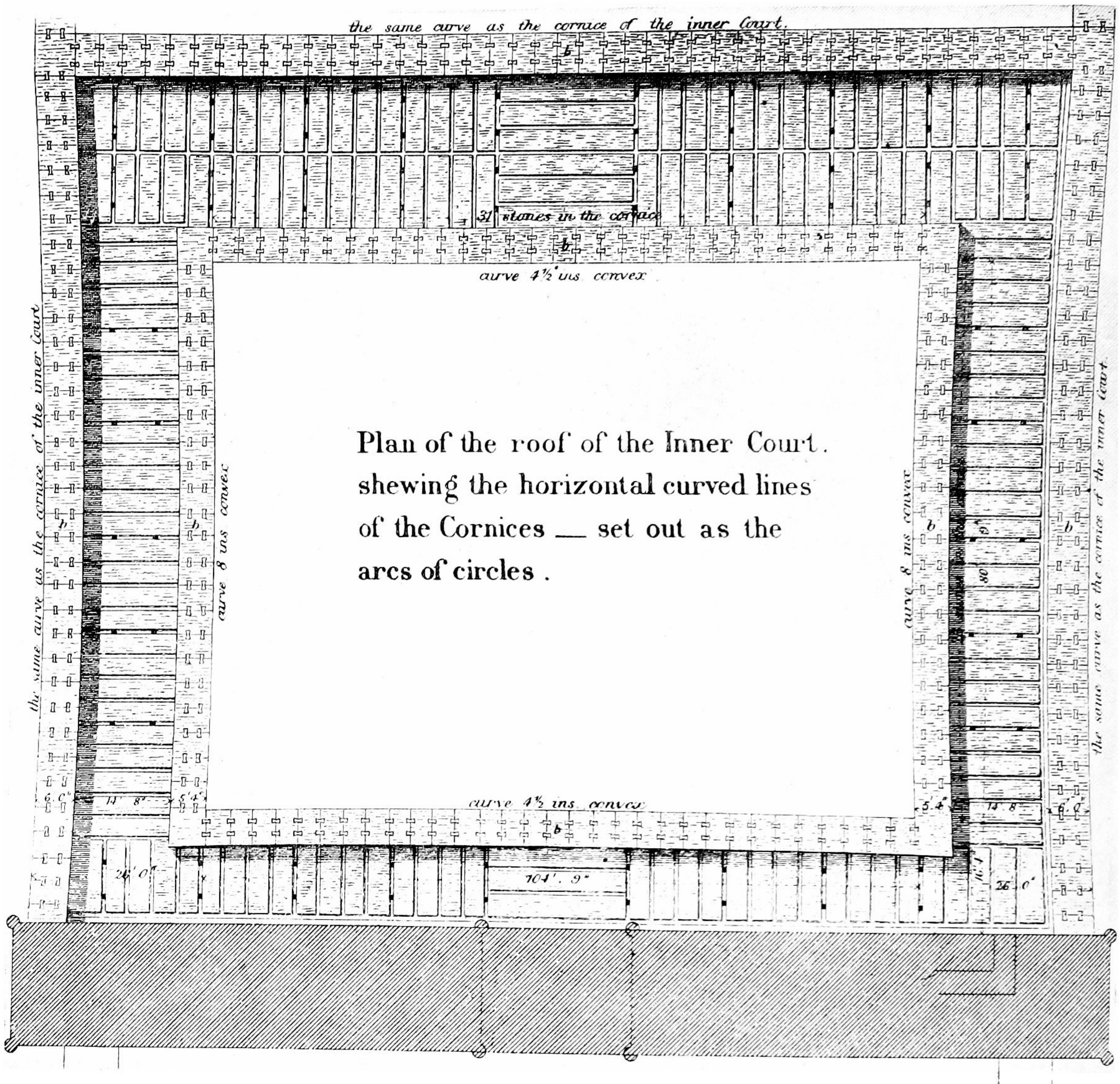



Fig. 24. Plan of the Roof of the Second Temple Court at Medinet Habou.

From Pennethorne's "Geometry and Optics of the Ancients." Showing curves in plan of 4½ inches convexity on the long sides of the court (104 feet 9 inches) and of 8 inches convexity on the short sides (80 feet 9 inches).

and its generally lotiform character), should lead others who mention his book to imitate the considerate delicacy of Mr. Penrose in passing lightly over its one great defect. Mr. Penrose says, in a foot-note to his second edition (p. 103): "An attempt has been made to reduce all the peculiarities of the Parthenon and similar buildings to a theory, *by which every part was calculated to produce a particular effect from an arbitrary point of view.*" No mention is made in this passage of Mr. Pennethorne, who is really referred to; and elsewhere (p. 23) Mr. Penrose speaks of Mr. Pennethorne's book as "a recent and beautifully illustrated work," without adverting to this theory. The real fact is that one part of the "Geometry and

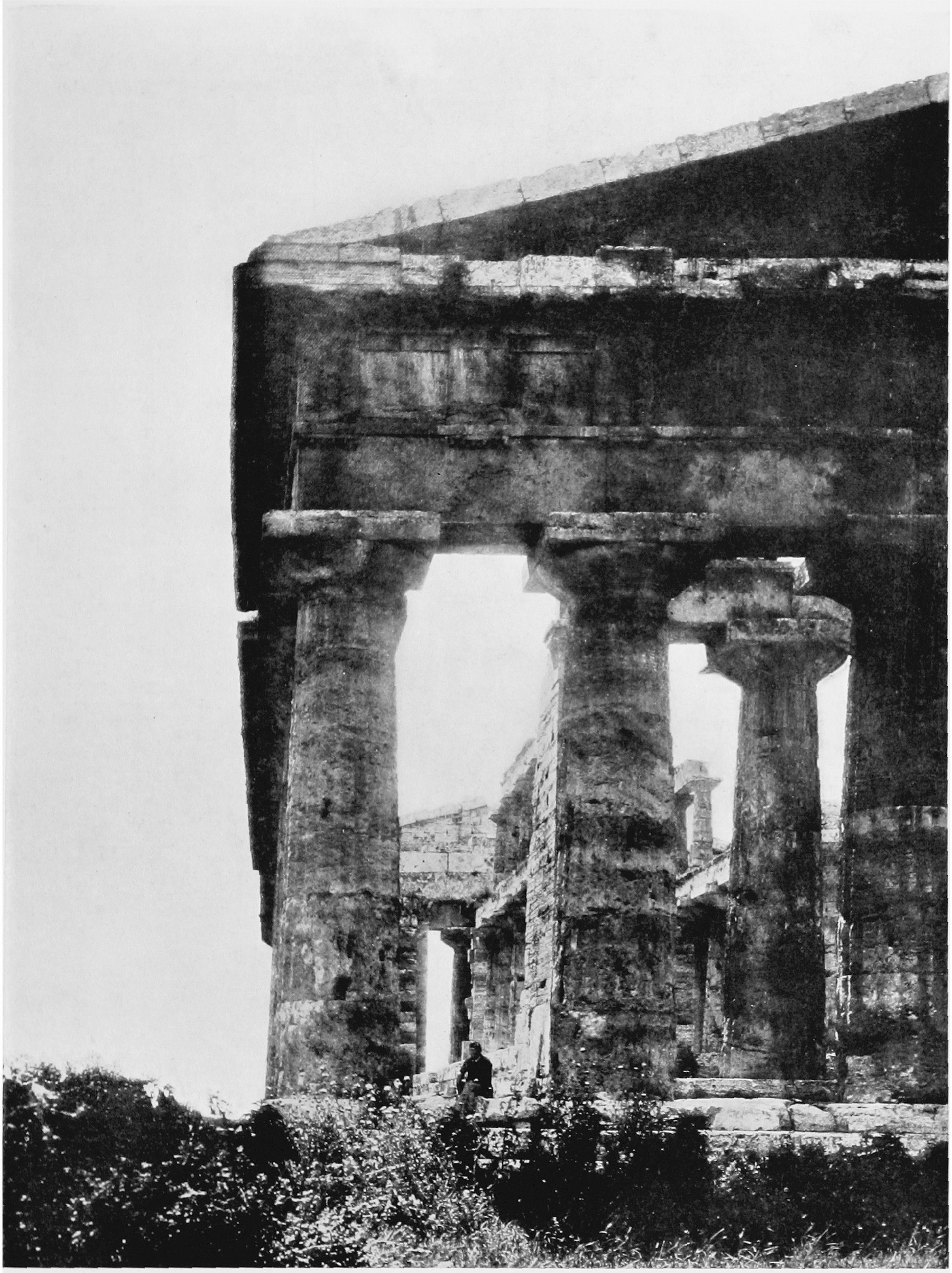


Fig. 25. South Flank of the so-called Temple of Poseidon at Pæstum. Fifth Century B.C.
Curves in plan in the capitals and cornice. Brooklyn Institute Museum photograph, series of 1895.

Fig. 26. North Flank of the so-called Temple of Poseidon at Pæstum. Fifth Century B.C.

Curves in plan in the capitals and cornice. Brooklyn Institute Museum photograph, series of 1895. The cornice curve is best sighted by holding the page upside down.

Optics of the Ancients"—viz., that which deals with the theory of Greek curvature—is a monument of hopelessly misapplied but very marvellous mathematical and geometrical knowledge, having for its argument and purpose the illustration of the undoubtedly erroneous idea that the Parthenon was designed to be seen from special points of view.

Mr. Pennethorne says, for instance, at p. 81 of his book: "Between the years 1835 and 1837, I had satisfied myself that the Athenian temples were all designed to be seen from fixed points of view." At p. 36 of his work, a series of complicated geometrical computations is preceded by an account of the local distribution and relation of the Acropolis monuments, in which this passage occurs: "Thus it was arranged that two perspective angular views of the Parthenon should be obtained—one at the northwest angle, designed from near the base of the statue of Minerva; the other at the southeast angle, designed for a point of view near to the works of art on the wall called Notium." Another passage, on p. 228, contains these words: "We have seen that in Greece this correction [of the curvature] was only applied to designs intended to be seen from angular points of view."

This feature of Mr. Pennethorne's work may be dismissed with the quotation of the noble passage which ends his introduction: "If I have been led into errors, I have had my reward in the study of much that is beautiful in Art, in Geometry, and in Nature, which has often afforded me real pleasure in many hours of retirement and of study."

Whatever the explanation of the neglect of Mr. Pennethorne's Egyptian observations may be, the fact is still there, that the first allusion to the Medinet Habou curves, in any other book on architecture, appears to have been made as recently as 1899, when Choisy's brief reference appeared.[a] This was nearly seventy years after the original discovery. The first discussion in any architectural essay of the problems raised by the original discovery appeared as recently as 1895. The first additional observations of architectural horizontal curves in Egypt which had been made since 1833 were published in the same essay.[b]

Thus certain optical theories, to be presently mentioned, which had been advanced to explain the Greek temple curves between the years 1838 and 1879, notably the theories of Mr. Penrose and of the distinguished optical experts August Thiersch and Guido Hauck, had been based upon inadequate knowledge of the facts. The only curves considered by these experts were the curves in elevation, i.e., *in vertical planes,* which appeared

[a] Choisy, *Histoire de l'Architecture,* Vol. I, p. 58.
[b] See Appendix[2] to this chapter.

on the exterior in Greek gabled buildings, whereas the Egyptian curves were *in horizontal planes* and convex to the standpoint of vision in the interior of an Egyptian temple court. Moreover, these authorities were not even aware of the purposed construction in classic architecture of two other phases of curvature, besides the rising curves in elevation which they had alone considered; viz., curves in plan convex to the standpoint of vision, and curves in plan concave to the standpoint of vision.

Greek curves in plan convex to the exterior were observed, for instance, by Jacob Burckhardt in the so-called temple of Poseidon at Pæstum (Figs. 25, 26).[a] Similar curves in plan convex to the exterior were also observed and measured by the writer in 1891, as occurring in the Maison Carrée at Nîmes, a Roman temple of the first or second century A.D., and their constructive existence was formally verified by the official city architect, M. A. Augière, and also by his predecessor in office, M. E. Chambaud.[b] That these curves in plan convex to the exterior, at Pæstum and at Nîmes, correspond in use and in optical effect, as regards the spectator, to those employed in Egypt, is a highly significant circumstance, and it is obvious that no optical theories on the subject of ancient architectural curvature can be considered as final which do not embrace this class of curves.

It was at an even later date that the Greek curves in horizontal planes which are *concave* to the exterior and to the standpoint of vision were first announced in such a way as to force the conclusion that they are also constructive arrangements which must be reckoned with by theoretic explanations. The latest mention of such a curve was made by Professor Allan Marquand, for the temple of Egesta, as recently as 1909.[c] This mention is later than the discovery, in 1904, of the carefully surveyed and explicitly described concave curves in the front of the temple at Cori, dating from the

[a] *Der Cicerone*, p. 8, 2d edition, 1869. Leipzig, E. A. Seeman. For later editions, including the French translation of this most important work, see p. 88. Thiersch mentions Burckhardt's observation incidentally, but discredits it on *a priori* grounds, as relating to deflections caused by accident. The recent important work by Koldewey and Puchstein on the temples of lower Italy and Sicily, which is frequently quoted in later pages (see p. 131), mentions Burckhardt's observation with reserve, and adds that there is an accidental widening, in the pavement at the middle of the cella, of 4 cm. This, however, would only account for 2 cm. outward movement to each side, whereas the curves evidently amount, as Burckhardt says, to several inches ("mehreren Zollen"). See, for example, Fig. 25, p. 37, showing the curve on the south flank. For some additional account of the constructive conditions indicating constructive purpose in these curves, see Appendix[1].

[b] For dates and titles of the original publications, see Appendix[2] of this chapter. The certificates of the architects who attested that the facts are constructive, and not due to accident, are quoted in the same Appendix.

[c] *Greek Architecture*, by Allan Marquand, Ph. D., L. H. D., Professor of Art and Archæology in Princeton University, pp. 115, 116: "The front horizontal cornice of the temple at Egesta curves inward in plan, whereas the lateral cornices of the so-called temple of Poseidon at Pæstum have a distinct outward curve in plan."

Fig. 27. Curve in Plan of the East Cornice, Maison Carrée at Nîmes.

Photographed for the Author in 1891. The deflection on the opposite (west) side has been measured and amounts to five inches. See Appendix[2].

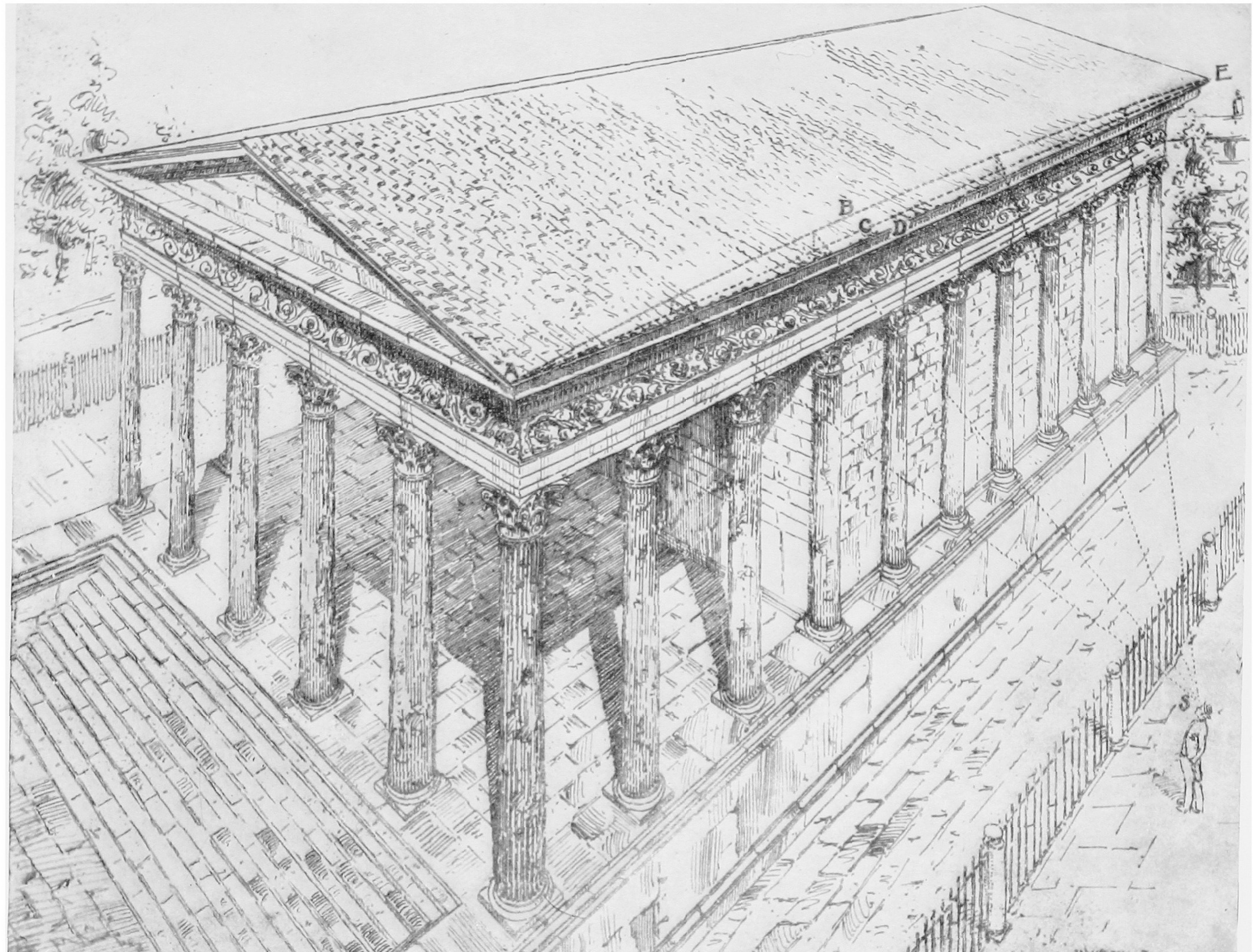



Fig. 28. Bird's-eye View of the Maison Carrée at Nîmes. West Side.

The curving dotted line illustrates the optical effect of the curve in plan as being that of a curve in elevation. See Appendix ⁴.

late Roman Republic (Figs. 29–32, pp. 47–51). This discovery was made and published by Professor Gustavo Giovannoni, assistant professor in the Royal School of Engineering Architects at Rome and at present date also president of the Architectural Society of Rome.[a] This observation by Professor Giovannoni was again preceded by a similar one which I had made on the east front of the so-called temple of Poseidon at Pæstum in 1895. The existence of this concave curvature was verified and recorded by a photograph of that date, although not published until 1907 (Figs. 1, 33, Frontispiece, and p. 53).[b]

Among these three observations at Egesta, Cori, and Pæstum, that of Profes-

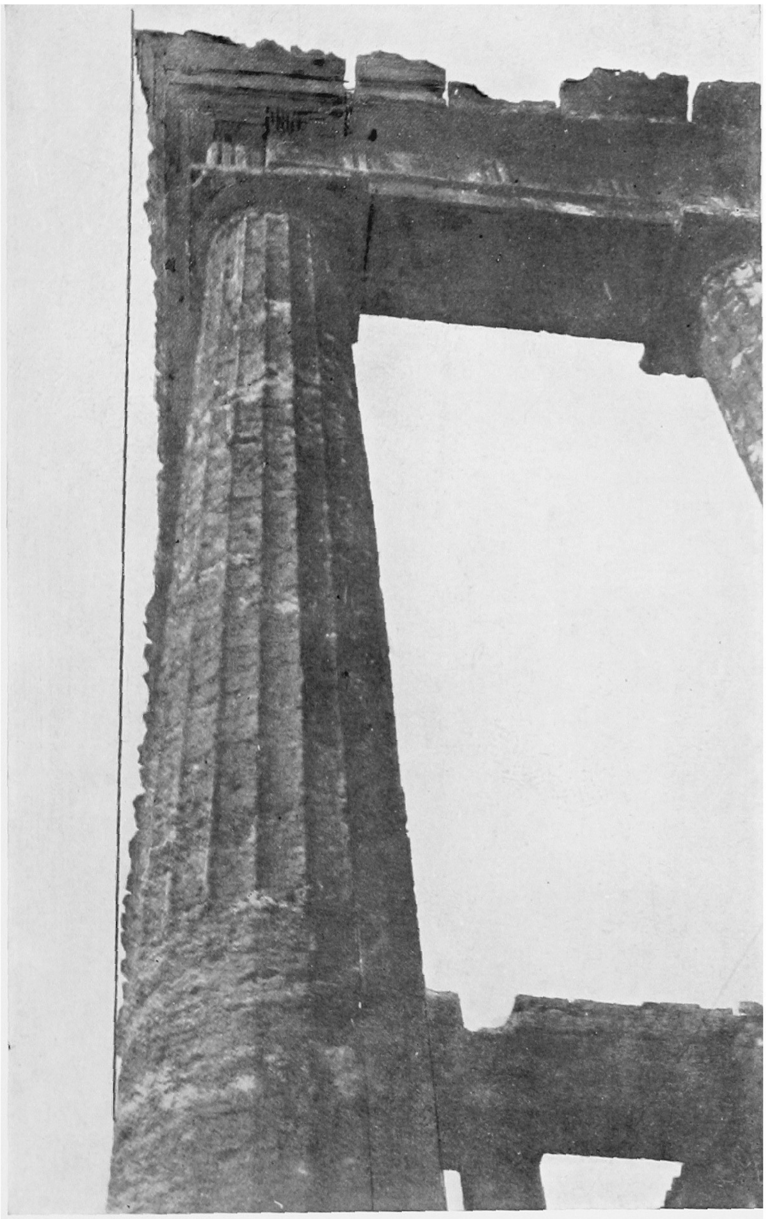


Fig. 29. Curve in Plan, Concave to Exterior, in the Gable Front of the Temple of Hercules at Cori. View looking up.

From a photograph kindly furnished by Professor Gustavo Giovannoni. Published in the "Mittheilungen des K. D. Archæologischen Instituts."

[a] *Mittheilungen des K. D. Archæologischen Instituts*, Vol. XXIII, pp. 109–130 (Rome, 1908): "La Curvatura delle Linee nel Tempio d'Ercole a Cori."

[b] The concave curve at Pæstum was originally published, with photograph, in the *Journal of the Archæological Institute of America*, Vol. XI, No. 2, 1907, in an article entitled "The Discovery, by Professor Gustavo Giovannoni, of Curves in Plan Concave to the Exterior in the Façade of the Temple of Cori." The same article also appeared in the *Architectural Record* for June, 1907. The amount of upper curvature at Cori, as quoted in these papers, was made known to me by the discoverer as first estimated by the eye. The accurate measurements subsequently taken, which supplant these offhand estimates, were published in the *Mittheilungen* and now appear in this work.

sor Giovannoni takes first rank, not only by priority of publication, but also by reason of the careful survey and the related drawings with measurements, which are reproduced in this chapter by his kind permission. This survey shows that the curve begins in the alignment of the columns on the platform, thus removing every suspicion of accident. The best description of the curves at Cori is offered by the illustrations (Figs. 29–32), and the photograph from Pæstum (Fig. 33, p. 53) is also a valuable illustration of the character of the Cori curves.

As bearing on some of the theories which have been advanced to explain the Greek curvatures, these various recent discoveries of curves in plan concave to the exterior and to the standpoint of the spectator have a revo-

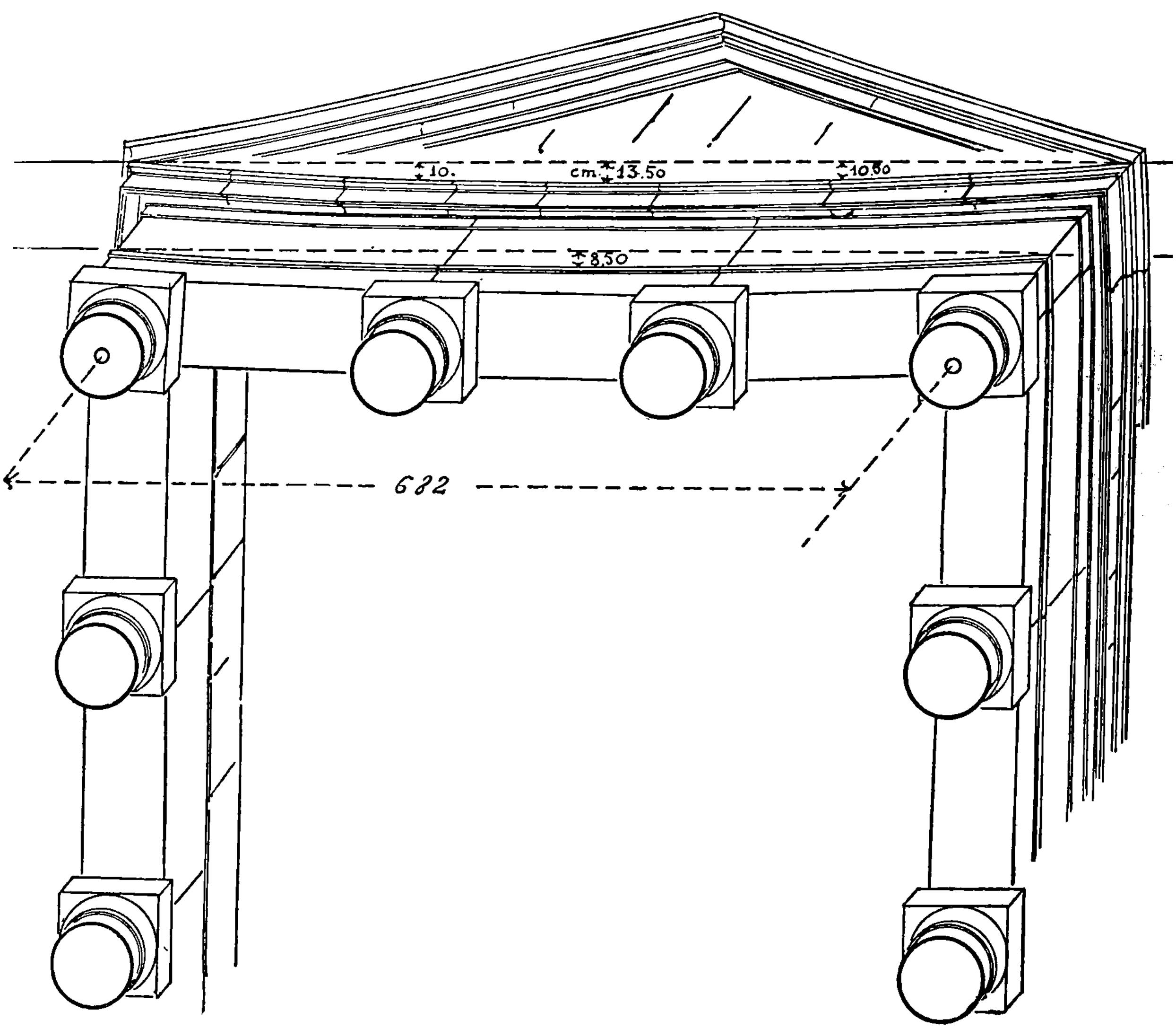



Fig. 30. Drawing of the Concave Curves at Cori, as seen looking up; with Surveyor's Measurements.
Published by courtesy of Professor Gustavo Giovannoni. From the "Mittheilungen des K. D. Archæologischen Instituts."

Fig. 31. The Temple of Hercules at Cori. Late Republican Period, about 80 B.C.

From a photograph kindly furnished by Professor Gustavo Giovannoni. A very perceptible downward curvature in the cornice under the gable may be sighted sideways. This is an optical effect, produced in the photograph by the concave curvature.

lutionary significance. It is, for instance, an almost universal popular impression at present that the ancient curves were intended to correct optical effects of downward sagging toward the centre, which are popularly supposed, and frequently said, to inhere generally in long architectural horizontal lines. Such a statement has even found its way into a compendious work of the highest standing and of generally unimpeachable accuracy, viz., Choisy's "Histoire de l'Architecture," which, in speaking of the Medinet

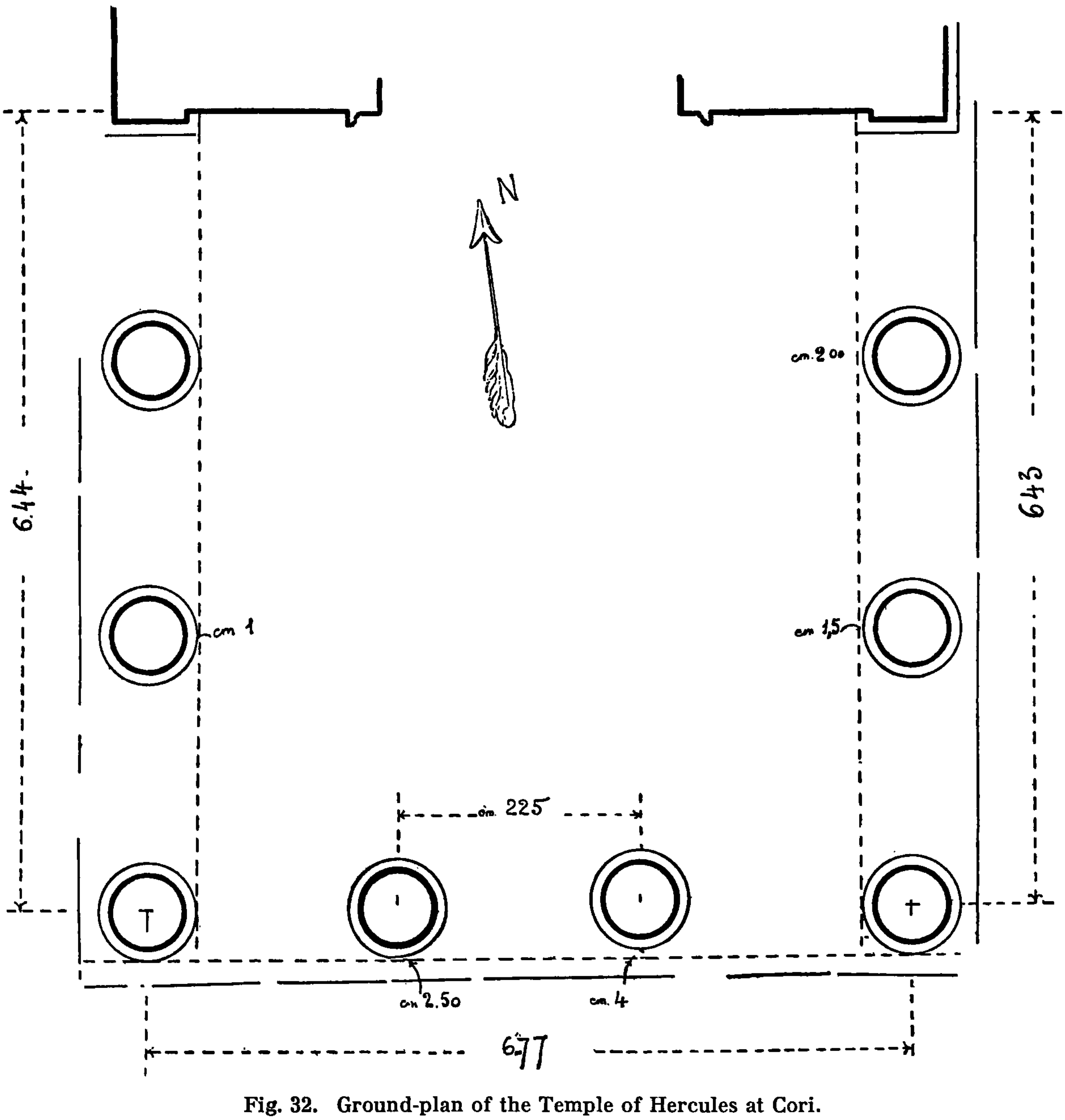



**Fig. 32.** Ground-plan of the Temple of Hercules at Cori.

Showing the concave curvature as beginning in the bases of the columns. Reproduced from the "Mittheilungen des K. D. Archæologischen Instituts," by courtesy of Professor Gustavo Giovannoni.

Habou curves, refers to "that peculiar deflection which is found when one looks at a long horizontal line such as that of an architrave: the line appears to sag downward at the centre."[a] This inadvertent statement is more than redeemed by M. Choisy's subsequent matter on the Greek curves, which does not repeat this error and which is characterized by correct views and apt expression. This passage will be quoted in its appropriate place in the next chapter. In view of this explicit utterance by M. Choisy as to the temperamental character and æsthetic significance of the Greek curvature, to be subsequently quoted, his statement here noticed may be considered as an inadvertence, or as an over-hasty acceptance of a widely quoted belief. The quotation is, however, of great value, as illustrating the remarkable diffusion of this error, which is again found in the first volume of Professor F. M. Simpson's excellent "History of Architectural Development" (1905). In this book we find the following passage (p. 92): "The lines of the entablature are often not straight but rise toward the centre in a convex curve; because long lines, when quite straight, appear to 'sag' or drop in the middle."[b]

The same error is found in the "History of Architecture," by Russell Sturgis, who does not unqualifiedly or decisively accept the debated explanation, but still assumes that the explanation cites and rests upon a real optical fact, viz., that "a long straight line above the eye tends to seem curved downward in the middle."[c]

The purpose of this chapter is to show that no optical expert who has made special optical contributions to the subject of the Greek curves has ever advanced this theory, which appears to be derived from a misapprehension of a wholly distinct proposition.

This subject will be approached by the observation that the *optical effect,* above the level of the eye, of a curve concave in plan to the standpoint of vision, is that of a curve in a vertical plane *which descends from the extremities toward the centre.*[d] Consequently the explanation which

[a] Vol. I, p. 58: "Cette singulière déformation qui se produit lorsqu'on regarde une longue ligne horizontale telle que celle d'une architrave: la ligne parait fléchir en son milieu."

From personal acquaintance with M. Choisy and from an active correspondence with him covering the years from 1903 to 1909, the date of his death, I am able to say that he laid no stress on the opinion expressed in this passage (published in 1899), and that he was as fully open to new light on this subject as he was upon that of the lotiform and Egyptian origin of the Ionic capital, which he had also overlooked in this volume, but which he subsequently accepted in correspondence with me as the true explanation.

[b] In justice to Professor Simpson it should be added that on the preceding page he mentions that "the object of these refinements was *in some cases to prevent a hard mechanical appearance in a building,* and in others to correct certain optical illusions."

[c] Vol. I, p. 184. See also Appendix[3].

[d] Appendix[4] of this chapter.

Fig. 33. Concave Curvature. East Front of the so-called Temple of Poseidon at Pæstum.

The curves occur in the alignment of the capitals and in the entablature. From a Brooklyn Institute Museum photograph, series of 1895.

has been so widely quoted and credited, that the ancient curves were intended to correct optical effects of sagging downward, is decisively thrown out of court by the recent discoveries at Egesta, Pæstum, and Cori, for it is exactly an optical effect of sagging downward which is actually produced by these concave curves in plan, as far as the upper horizontal lines are concerned. This downward sagging effect may be easily seen in the cornice under the gable in the front view of the temple at Cori (Fig. 31, p. 49), and results purely from the concavity in plan.

So conclusive an argument leads us to examine the previous standing of the given popular explanation. The opportunity is a convenient one to point out, later on in this chapter, that it is originally a misapprehension or misquotation of an entirely different proposition. It is a modern prejudice that architectural lines ought to be straight. Consequently the suggestion that the Greeks curved their architectural lines in order that they might *appear* straight, instantly appeals to this prejudice and is easily accepted without farther thought or examination. The impression that all horizontal architectural lines appear to sag at the centre, as far as it prevails among architects, may be due to the occasional practice of cambering interior tie beams under a gabled roof, but the problem of optical effects in such interiors has no relation to the general but mistaken belief.

The error of this opinion is shown by the elementary principle of perspective that horizontal lines above the level of the eye, and especially on near approach, curve downward *toward the extremities, and not toward the centre.*

This is most easily realised by assuming the position of the spectator to be opposite and near to the centre of a long building, of such dimensions that the head has to be turned first in one direction and then in the other in order to take in the entire upper line. As the really horizontal upper line to the left of the spectator will descend optically in perspective toward the left, and as the really horizontal upper line to the right of the spectator will descend optically toward the right, it is manifest that the eye, in passing from left to right or from right to left, must see the whole horizontal line, optically, as a curve descending toward the extremities and highest in the middle.

It is equally true that all lines which descend in perspective in a single direction must descend in a curve, optically speaking, because the line which is really straight and horizontal appears to descend in gradually increasing amount according to the distance from the eye. Consequently an actually horizontal straight line which, optically speaking, changes direction from point to point, must necessarily change direction, optically speaking, in a curve. It is only the mental knowledge that the line is really straight and horizontal which interferes with the perception that the line is really seen as a curve.

This interference of a mental conviction, based on general positive knowledge, with an actual optical appearance, is a well-established fact. The interference of the brain with the true facts of vision has been ably described by Dr. Guido Hauck.[a] Dr. Hauck found that the ability to see the rising curves which optically exist in all horizontal lines above the level of the eye (unless interfered with by other lines) was strongest in women and in the persons whom he calls "Naturmenschen," among whom he includes artists, whereas persons with mathematical and scientific training were frequently unable to see the curves at all. He also found, in his own experience, a progressive improvement in his ability to distinguish the curves as actually seen by the eye. He also found that optical curves, in lines really straight and horizontal, could be seen in a line of separated lights illuminating an architectural line at night, when they could not be seen in the same architectural line by daylight. The mental conviction had an effect on the continuous line which it did not have on separate points of artificial light, not visibly connected by the architectural line. (I have had the same experience.)

The mental corrections of optical appearances which are described by Dr. Hauck have a curious analogy in the experience of Mr. John W. Beatty, M. A., Director of Fine Arts in the Carnegie Institute at Pittsburg, Pennsylvania. The following extract from a letter to me on this subject is published by his permission:

> Briefly put, my experience was this: When I first put on glasses for astigmatism, perpendicular lines appeared not parallel, being wide at top; in the size of a newspaper page, about one and one-half inches wider than normal. When I had worn the glasses for several months, lines seemed again parallel. Now, when I take the glasses off, lines are again not parallel, but wider at the bottom. Dr. Lippincott's theory was that I had always made mental correction, and lines recorded on the retina out of parallel were made to appear parallel by virtue of mental correction. This seems to be absolutely proven by the history of the case, as above briefly outlined. When I take the glasses off now I see lines imperfectly at the instant of time, because the brain is not given time to correct the defect. The fact that the greater width is now at the bottom without glasses, whereas it was at the top with glasses when they were first used, is significant. You will find the reference to my case in the "Archives of Ophthalmology," Vol. XVIII (1889), p. 18, and more particularly p. 28.

[a] In the work previously cited, p. 20, foot-note[b], and p. 25.

All these points assist us to understand why lines which are optically seen as curves are not generally recognised as curves by ordinary vision. The reasons are physiological. These points also enable us to understand that the perception of the curves which are optically present in the facts of vision varies according to temperament and according to training. As a matter of fact, there is no perspective which is not curvilinear, but as these perspective curves are too delicate to be represented in the dimensions of pictures, instruction in perspective, as regards draughtsmen and painters, generally ignores them, and hence does not tend to counteract the general indifference to their existence, which is due to mental correction.

These points bear on the popular error that there is a natural sagging effect in architectural horizontal lines above the level of the eye; *but no optical expert who has made a special study of the Greek curves has ever suggested that such a general sagging effect exists.*

Thus, the first investigator who made publication on the subject supposed that the Parthenon rising curves in elevation were intended to accent and increase perspective effect, because they develop and accent a form of curve *which already exists* in the normal optical appearance. This investigator was Hoffer.[a] So far from suggesting that the Greek curves in elevation were intended to correct an effect of sagging, he supposed that they were intended to enhance and exaggerate a curve of exactly contrary character, and this curve was properly and expressly mentioned by him as the ordinary optical appearance due to perspective. Hoffer's views as to a development of perspective effect by the Greek horizontal curves in elevation are as follows:[b]

As it appears to me, the Greeks made the great sacrifices which the really complicated construction of the curved lines demanded, on behalf of their feeling for beauty and of optical laws. I have already expressed myself as to the æsthetic motives,[c] and it only remains to say something of the motives which were derived from optics and perspective effect.

*Every long façade appears, when the spectator stands opposite its centre and looks towards the two ends, to be lower in their direction,* and the longer the façade, the more this appears to be the case. Is it not possible that the Greeks, who were intimately acquainted with the laws of optics and perspective, had the idea of making their buildings appear longer than they really were by actually introducing these downward bends into the construction? I am well aware that this explanation will appear far-fetched to many of my readers, and yet I believe it will be admitted that this effect is even obtained in the pictorial reproduction, and that the Greeks took such pains with the exterior effect of their buildings that we may credit them with this idea.

[a] Chapter I, p. 3.
[b] Tr. from the *Wiener Bauzeitung* for 1838, No. 42, p. 379.
[c] This passage is quoted in the next chapter.

This theory of Hoffer will be considered in a later chapter as an explanation of the Greek curvature. It is only quoted here to illustrate the point that horizontal lines, above the level of the eye, do not generally appear to sag downward toward the centre.

The only general optical effect of sagging toward the centre is that due to perspective, as found in really level and flat surfaces or horizontal lines *below the level of the eye.* It is an effect of curvilinear perspective (and all perspective is curvilinear as a matter of fact) that all plane surfaces *below* the level of the eye must tend optically to "dish"; that is, to appear remotely like a dish or bowl. Aeronauts find this appearance in the earth's surface when raised above it in a balloon, for the same optical reason. The converse and opposed effect is the dome-shaped appearance of the sky. We have also seen (Appendix[5], Chapter I) that Vitruvius directs that the platform of the temple shall be built with rising curves in elevation, lest it appear "alveolated" (like the bed of a channel).

Although the explanation of Vitruvius has been generally ignored by modern scholars, presumably on the ground that he was dependent in such matters on earlier Greek authors whose works have been lost, and which he did not himself thoroughly understand (which is no doubt largely true), it ought to be supposed that Vitruvius is speaking of an effect of "alveolation" for the spectator standing *on the platform and looking down at it.* It has been generally assumed that Vitruvius is speaking of an effect for the spectator *when looking at* the temple. The elaborate explanation of Thiersch, for instance, assumes this, and he is the only modern author who has attempted a critical explanation of this passage.[a]

Choisy takes the correct view in his "Histoire de l'Architecture" (although he does not discuss or debate the Vitruvian passage), that the curves of the platform would tend to correct an appearance of "dishing" for the spectator on the platform,[b] but he adds justly that this explanation is insufficient.[c]

However, if the passage in Vitruvius be interpreted as applying to an observer *on the platform,* it needs no explanation as far as the platform is concerned. As regards the curves of the Greek temple platform, it should always be remembered that they do not relate solely to the outer lines, but that they also include the surface. The entire platform surface of the

[a] See Appendix[5] of this chapter.

[b] "Un carrelage exactement plan semble déprimé en son milieu: Au Parthénon, cette dépression apparente est compensée par un léger bombement." *Histoire de l'Architecture,* Vol. I, p. 407.

[c] See quotation at p. 92.

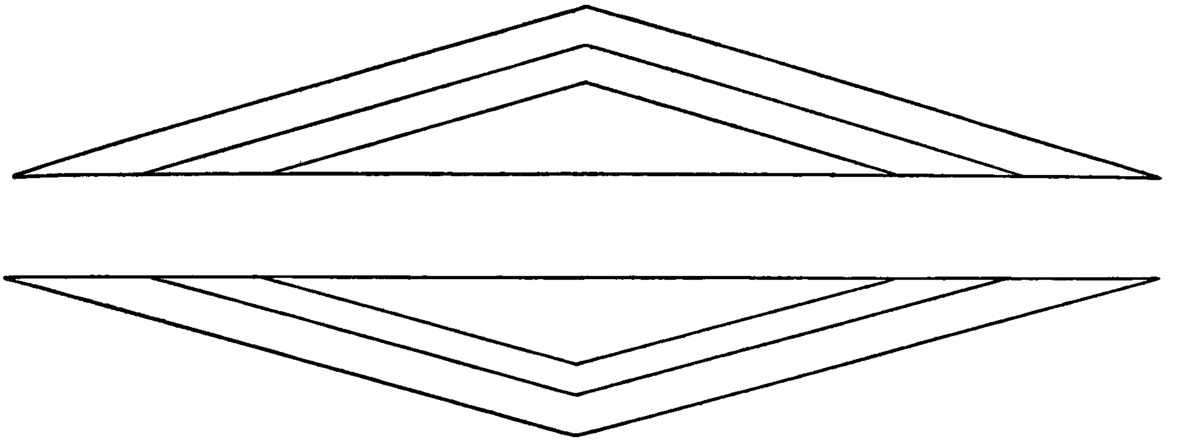


Fig. 34. Optical Illusion of Curving Lines, produced by Acute Angles.

The lines which appear to curve toward each other are really straight and parallel. From Thiersch, "Optische Täuschungen auf dem Gebiete der Architektur."

Parthenon is delicately spherical[a] (*bombé* is the French expression), and this gives additional interest to the suggested interpretation of the passage in Vitruvius, which cannot, however, be applied to the entablatures, and is therefore unsatisfactory, even when the rising curves in elevation (as distinct from curves in plan) are the only ones considered.[b]

The mistaken impression that the Greek rising curves in elevation were intended to correct an effect of sagging may have its cause, to some extent, in an uncritical popularisation of the explanation of Vitruvius, which, as a matter of fact, does not at all refer to the lines of the entablature. It appears most likely, however, that the debated error is mainly a misapprehension or misquotation of the theory of Penrose, who never, as a matter of fact, suggested any such appearance in horizontal lines as being a general rule. Penrose only based his theory that the Greek curvature was originally an optical correction, on the optical tendency of a really straight horizontal cornice to curve downward *under a gable,* because the lower

[a] Penrose, p. 34: "These sections show that (although not very regularly) a certain amount of rise prevails through the whole building." On this page Penrose accepts the interpretation of Vitruvius here favored, *as regards the stylobate,* but, rather strangely, does not recur to the matter in his Chapter XV, which is the one specially devoted to explanations of the curvature.

[b] In Choisy's preface to his *Vitruve* (Paris, Lahure, 1909) the opinion is expressed that Vitruvius had very slight knowledge of the Greek temples of earlier date than the second century B.C., and that entire chapters of his work are borrowed from the theorists of the Alexandrian period of the first and second centuries B.C. (who wrote their books in a period of sophistication and long after the best monuments of Greek architecture had been erected). The habitual attitude of modern scholars toward Vitruvius since the beginning of the Greek Revival and the special studies of the Greek monuments, as distinguished from the Roman studies of earlier date, has been influenced by the general suspicion that he either copied incompletely, or understood imperfectly, the books of the earlier Greek architects.

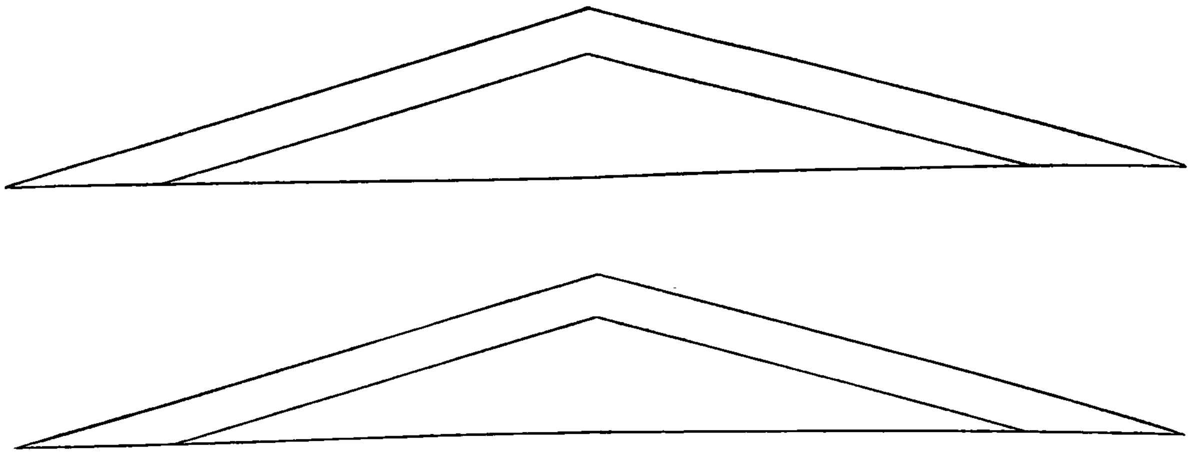


Fig. 35. Drawings to illustrate the Penrose Theory of the Gable Correction.

The line under the upper gable appears to sag downward and is really straight. The line under the lower gable is curved upward to correct the illusion, and appears to be straight. From Thiersch.

acute angles of the gable tend to appear wider than they actually are, and therefore the bottom line appears depressed at the angles and consequently curved. The exact words in which this theory is stated are as follows (p. 104):

> There can be little doubt that the origin of the horizontal curve was to obviate a disagreeable effect produced by the contrast of the horizontal with the inclined lines of a flat pediment, such as the *ætos* of a Greek temple, causing the former (*i.e.*, the cornice) to appear deflected from the angles. As the line so affected is continuous, this deflection appears to take place in a curved line, and within ordinary limits it becomes the more apparent the more acute the angle which the contrasting lines make with each other.

Instances of the well-known illusion which causes an acute angle to appear wider than it really is are offered by Figs. 34–38, pp. 59–61. One of these figures (35) illustrates the optical correction by which the apparently curving line is made to appear straight. The physiological causes of this

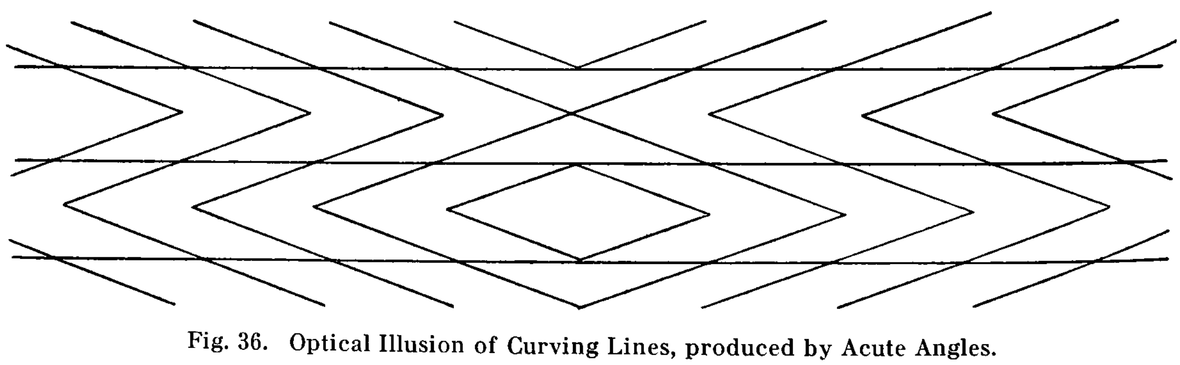


Fig. 36. Optical Illusion of Curving Lines, produced by Acute Angles.

The lines which appear to curve toward, or away from, each other are really straight and parallel. From Thiersch.

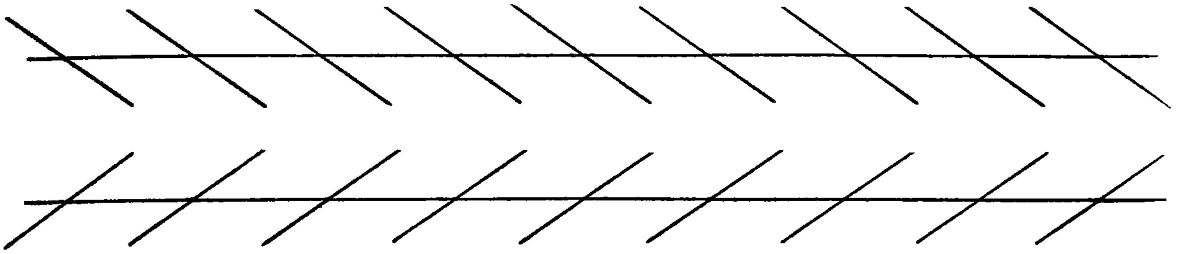


Fig. 37. Optical Illusion of Converging Lines, produced by Acute Angles.
The lines which appear to converge in the direction from right to left are really parallel. From Thiersch.

illusion have been explained by Helmholtz[a] and by Wundt.[b] The following simple experiment is an additional illustration of the tendency of acute angles to appear wider than they really are. If a rug, corresponding generally to the size and shape of the room in which it is placed and of slightly smaller size, be laid down slightly askew, each wall of the room will appear to recede from the corresponding side of the rug, in the direction toward the widening of the angle.

Thus, according to Penrose, the rising curve *under the gable* was intended to counteract and correct an effect which was due *to the angles of the gable.* As far as the flanks are concerned, he supposed the curves to be explained by the sentiment of beauty and the appearance of strength,[c] but to have been *originally suggested* by the use of the curve as an optical correction under the gable. The curves on the flanks were, therefore, supposed by Penrose to have been an afterthought, not found in the most ancient temples. In other words, a later use of the curves on the flanks was thought to have been first suggested by an earlier use of

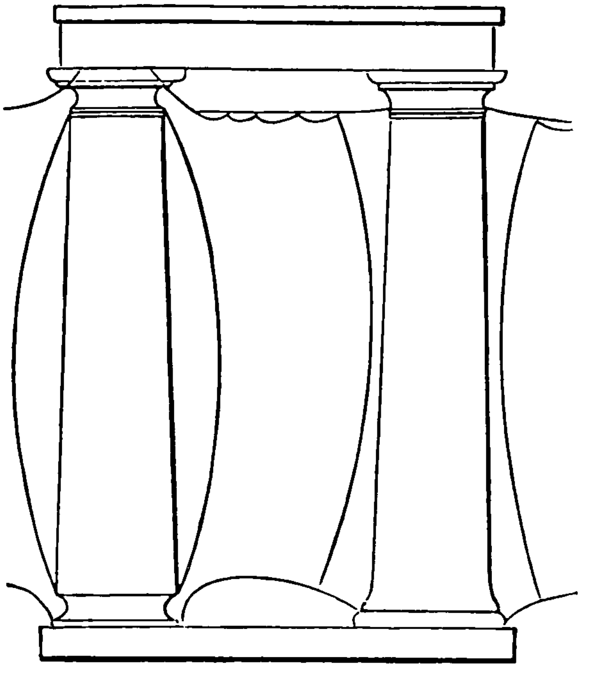


Fig. 38. Optical Illusions of Concavity and Convexity in Drawings of Columns whose Sides are Straight and whose Forms are Identical. Illustration of the tendency of acute angles to appear wider than they really are. The sides of the column on the left appear concave and those of the really similar column on the right appear convex. From Penrose.

[a] In *Populäre Wissenschaftliche Vorträge,* III. Heft, p. 571. Braunschweig, Vieweg und Sohn, 1876.

[b] In *Grundzüge der Physiologischen Psychologie,* p. 563. Magdeburg, Faber, 1872–78. (These references are furnished by Hauck.)

[c] See Appendix[5], Chapter III.

curves under the gables; *but the reason for the use on the flanks was not supposed to have been the same.*

Since the theory of Penrose as to the use of the Greek curves as optical corrections was derived from optical effects which are confined to the straight lines under a gable, it is evident that his theory could not apply to a building like an Egyptian temple court, which has no gables, and that it consequently has no present value in any effort to formulate a philosophy which covers the subject of ancient curvature in general. We are concerned, however, with two points at once—a mistaken popular impression and the theory of Penrose. Aside from the debated error, we are, therefore, also obliged to consider the later and present standing of the Penrose gable theory, *as discussed by experts who were also unaware of the existence of the Egyptian curves in plan.*

It is already apparent that the Penrose gable theory, which appears to be the original form of the debated popular error as to sagging horizontal lines, is really a wholly distinct proposition. Even the gable theory has, however, never been accepted, or even favorably mentioned, by any German authority. This will appear from a mass of quotations to be made in the following chapter. Moreover, it has been vigorously and successfully contested by the two greatest German experts who have subsequently discussed the Greek horizontal curves in elevation from the standpoint of the specialist in optics.

The first of these was Thiersch, who added to a variety of solid arguments one which must appeal to every understanding, whether that of an expert or not.[a] The argument is this: If Penrose was correct in believing that the curves of the entablature and cornice on the gable fronts of the temple were intended as an optical correction under the gable, and to make the lines appear straight, how does it then happen that the platform is also curved, for which no such gable effect exists? It is not necessary to rehearse or debate, at this point, the theory substituted by Thiersch, who thus and otherwise contested the gable theory of Penrose, because it has also been displaced by subsequent discoveries and publications.[b] One of these publications was that of Guido Hauck, already mentioned (p. 56).

Although Hauck abandoned the new explanation offered by Thiersch, he approved, rehearsed, and elaborated the arguments which led that scholar to reject the theory of Penrose; especially dwelling on the point

[a] "Optische Täuschungen auf dem Gebiete der Architectur," *Zeitschrift für Bauwesen,* XXIII. Ernst und Korn, Berlin, 1873.

[b] For the theories of Thiersch and Hauck, see Appendix[5].

that the stylobate need not have been curved if the object of the curve was to correct an apparent deflection under the gable. Both Thiersch and Hauck also urge the sensible view, that to consider the curves of the entablature on the flanks of the Greek temples as purely an afterthought is a far-fetched and wholly unsupported hypothesis.

It should also be remarked that the theories which were suggested by Thiersch and Hauck, and which were proposed to supplant the theory of Penrose, make no reference to a general sagging effect in horizontal lines, and Hauck expressly develops the fact that horizontal lines above the level of the eye tend normally to curve downward toward the extremities instead of curving upward toward the extremities, as they would if they had a sagging effect. Thiersch alludes to the same fact as holding for near approach.

The publication of Hauck is undoubtedly the most valuable and far-reaching contribution to the optics of rising curves in elevation which has ever been made. But as an explanation of the subject of curvilinear refinements, viewed as a whole, it has also been displaced, and therefore needs no detailed description. It is sufficient to say that it is based, like the theory of Thiersch, on the form of the Greek temple and on the idea that the curves were first used by the Greeks, and that these curves were always rising curves in elevation. In preference to a labored effort to describe and com-

**Fig. 39.** Temple of Concord at Girgenti, showing Curves in Elevation on the South Flank Stylobate.

Photographed by Mr. L. E. Rowe, Director of the Rhode Island School of Design.

bat these successive theories, it has seemed preferable to show (as has been done), in advance of mentioning them, why they have become untenable. One main reason, among others, is the obvious one that neither Thiersch nor Hauck was acquainted with the Egyptian horizontal curvature.[a]

By the preceding summary two results are fairly well established. First, the popular impression that the Greek curves were intended to make the lines look straight, and to correct effects of sagging, supposed to be inherent in all horizontal architectural lines, is without optical authority. The second result is this. So far as Penrose is concerned, he only suggested a sagging effect under the gables at the ends of a temple as the explanation of the curves. Against this theory the following points may be urged. It has not been accepted or favorably mentioned by any French or German expert as a general explanation. It has been vigorously opposed by two distinguished experts in optics, and the theory of Hoffer is also opposed to it in principle. Above all, it is thrown out of court by the observations in Egypt.

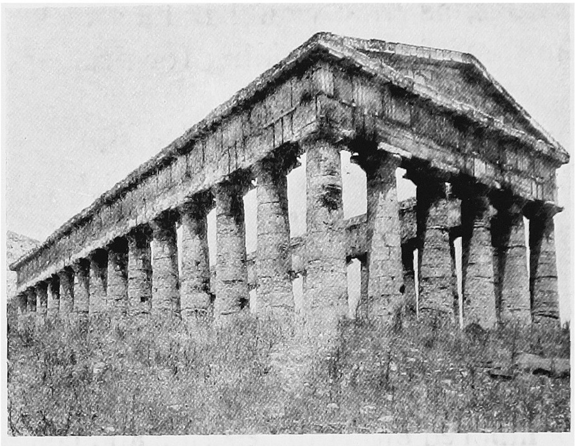


Fig. 40. The Temple at Egesta. Fifth Century B.C.

It may also be mentioned that the Brooklyn Institute Museum survey of 1895, which established the existence of curves on the flanks of the so-called temple of Concord at Girgenti, also established the *absence of curvature* in the entablature of the west front, thus again discrediting the theory that the curves on the flanks were an afterthought, and that those under the gables were the original ones and the more important ones.[b]

We are now able to return to the concave curves in plan at Egesta, Cori, and Pæstum, which, aside from all previous arguments, dispose for all time, not only of the special theory of Penrose, but also of the mistaken impression that the Greek curves were intended to correct a general sagging effect and to make the lines look straight.

It also appears possible that a still more celebrated Greek temple may offer another instance of constructive concave curvature in plan. Both Hoffer and Pennethorne observed curves in plan concave to the exterior *on*

[a] As explained at the opening of the chapter, see pp. 35–42.
[b] See Fig. 41, p. 65.

Fig. 41. Temple of Concord at Girgenti. West Front, in Parallel Perspective.

Showing the absence of curvature in the stylobate and in the entablature. Brooklyn Institute Museum photograph, series of 1895.

*the fronts of the Parthenon.* Hoffer explicitly described these curves and measured them. The plan of these concave curves, with the measurements, is published in the "Wiener Bauzeitung" of 1838.[a]

Hoffer described these curves as beginning in the capitals, as continuing in the entablature and sloping cornice, but *as not being found* in the face of the tympanum, *i.e.,* in the background of the gable. They amount to about two inches at the cornice, which is also the amount of the rising curves in elevation at the ends of the temple. Penrose quotes the corresponding observation of Pennethorne, as found in Leake's "Topography of Athens," p. 573,[b] but gives his reasons for believing these curves to be accidental.

In deference to Penrose, Pennethorne, in 1878, accepted this view. The argument of Penrose is that the gaps between joints were greater in the rear than in the front. Hoffer's observation that the tympanum surface is without curvature would appear to suggest that the curves below it could hardly be due to accidental movement. No decision on such a head can be reached, or even suggested, in this work, and the explosion which ruined the Parthenon is not to be forgotten; but it is surely worth remembering, in view of the concave curves in plan at Cori, that concave curves in plan in the Parthenon gable fronts were observed, measured, and published in 1838, by Hoffer, as constructive. Although the existence of these concave Parthenon curves has been generally ignored, they have been accepted as constructive by two German experts who were well aware of the adverse opinion of Penrose. One of these experts was Reber;[c] the other was the gifted Professor Adolf Michaelis, whose celebrated work on the Parthenon still holds a unique place in the literature of Greek art. The explanation offered by Michaelis for this concave curvature—that it was calculated to produce more varied effects of light and shadow—would cover all other similar cases of concave curvature in the ancient temples, and it appears to be the true explanation. It is quoted in the next chapter (p. 91).

It is not necessary, however, to enter here into optical explanations of what is agreeable to the eye. That both the Greek and the mediæval architectural curvatures appeal to the temperament and understanding of many modern architects, artists, and art critics is beyond debate. That curved lines were considered preferable to straight ones, in certain cases, by a large number both of ancient and of mediæval builders may also be considered as positively established. We may therefore pursue this subject in the next chapter by citing the views of a large number of the most distinguished

[a] No. 43, p. 387, and Pl. CCXXXVIII, Fig. 4. [b] See Chapter I, p. 5. [c] See Appendix[6].

modern authorities as to the æsthetic and artistic significance of the Greek curvature.

It will appear from these opinions that the classic horizontal curvatures were temperamental refinements inspired by the sentiment of beauty and by artistic preference, and not by a desire to exaggerate by optical correction the formalism, stiffness, and rigidity of straight lines. It will also appear that the highest authorities on the general history of art had formed these opinions during the earlier stages of the modern discoveries of the Greek refinements, and long before the evidence had been accumulated which has been cited in this chapter, to the effect that the Greek curves were not intended to make the architectural lines look straight.

Fig. 42. Doric Capital and Abacus,
Temple of Zeus, Olympia.

# APPENDIX. CHAPTER II

[1] The entire passage in which Burckhardt's observation at Pæstum is recorded is quoted in the next chapter (p. 88), together with a mention of his great distinction among the art historians of the nineteenth century and of the remarkable importance and high standing of his *Cicerone.* From this quotation it will appear that the possibility of accident in the case of these convex curvatures in plan, as due to earthquakes or careless laying out, was debated by Burckhardt, and that this explanation was held to be untenable.

Fig. 43. Temple at Edfou. Third Century B.C.

Thiersch's suggestion[a] refers in the first instance to the concave curvatures of the Parthenon, and is to the effect that these curves in plan must be due to the general tendency of ancient entablatures to spread at the joints. Burckhardt's observation at Pæstum is then mentioned as presumably open to the same explanation. Thiersch does not allude to any observations of his own at Pæstum as substantiating this suggestion.

The fact that these convex curvatures are found in the lines of the capitals of the Poseidon temple, as well as in the entablatures and cornices, is a preliminary proof that shifts in the joints of the entablature could not be a sufficient explanation. Koldewey and Puchstein refer (p. 28) to an accidental depression in the pavement of the cella as showing that a widening of 4 cm., or 1½ inches, in the width of the cella at the centre, is due to the same accident; and on a preceding page they quote Burckhardt's observation with a reference to this point. However, these authors are also authority for the fact that there is no corresponding depression of the pavement in the stylobate of the porticoes, because they have expressly established the existence of a rising convexity in the stylobate of each flank (see p. 126). The exist-

Fig. 44. Temple Court at Edfou.

[a] See foot-note[a], p. 42.

ence of this rising convexity in elevation under the colonnades of the flanks shows that their convex curvatures in plan cannot be due to accidental depression. Moreover, the widening of the cella, if accidental, would account for only a ¾ inch convexity to each side, whereas Burckhardt's computation of "several inches" to each side is obviously supported by the photographs published in this work (Figs. 25, 26, pp. 37, 39).[a]

Fig. 45. Rear Temple Court at Luxor. About 1400 B.C.

We should thus be reduced, on the theory of accident, to the supposition that each flank colonnade had been tipped outward, in gradually increasing degree, in the direction of its centre. But such tipping would have occasioned shifts in the joints, with gaping joints on the inside of each shaft and with grinding and chipped joints on the outside. These serious evidences of disintegration have certainly never been observed in the shafts of this temple, which are notably firm and solid in their general appearance.

To these various considerations we may add two others. First: the effects of earthquakes would presumably have affected both sides of the temple in one given direction, rather than in two opposed directions. Second: the absence of any deflections of alignment, either of regular or irregular character, in two other important ruins at Pæstum, viz., the so-called Basilica (Fig. 110, p. 183) and the so-called temple of Ceres (Fig. 87, p. 153), are almost conclusive proof, even without other evidence, that the curvatures in plan of the so-called temple of Poseidon are not caused by accident. If this were the case, these other temples, which are generally in a much worse state of ruin, would exhibit at least equally marked deflections of alignment.

As to the absence of these deflections in the temple of Ceres and in the Basilica, our own party of observation could not observe any in 1895. This testimony is supplemented by that of the distinguished author, journalist, and critic, Charles Dudley Warner (1829–1900), associate editor of *Harper's Magazine* after 1884, who visited Pæstum on his way to Egypt, during the seventies. His observations are recorded in *My Winter on the Nile* (Houghton, Mifflin, 1876; 12th edition, 1890; p. 21) as follows:

"At first we thought the temple small, and did not even realise its two hundred feet of length, but the longer we looked at it the larger it grew to the eye, until it seemed to expand into gigantic size; and from whatever point it was viewed, its harmonious proportions were an increasing delight. The beauty is not in any ornament, for even the pediment is and always was vacant, but in its admirable lines.

[a] Burckhardt's mention of "several inches" curvature refers particularly to the right flank when facing the eastern front—*i.e.*, to the north side. The photograph for this flank, Fig. 26, shows rather less curvature than appears on the south flank, Fig. 25.

The two other temples are fine specimens of Greek architecture, also Doric, pure and without fault, with a little tendency to depart from severe simplicity in the curve of the capitals, and yet did not interest us. They are of a period only a little later than the temple of Neptune,[a] and that model was before their builders, yet they missed the extraordinary—many say almost spiritual—beauty of that edifice. We sought the reason, and found it in the fact that there are absolutely no straight lines in the temple of Neptune. The side rows of columns curve a little out; the end rows curve a little in; at the ends the base line of the columns curves a trifle from the sides to the centre, and the line of the architrave does the same. This may bewilder the eye and mislead the judgment as to size and distance, but the effect is more agreeable than almost any other I know in architecture. It is not repeated in the other temples, the builders of which do not seem to have had its secret."

[2] Goodyear, in the *Architectural Record,* June, 1895, Vol. IV, No. 4. The article is entitled "A Discovery of Greek Horizontal Curves in the Maison Carrée at Nîmes." This was subsequently reprinted in the *Smithsonian Reports,* Washington, Government Printing Office, 1896. (The published date of the report is "1894," but the actual publication was belated.)

Besides the subject indicated by the title, this article included my observations in Egypt, which were made in 1891. The temple of Edfou, where I then observed curves similar to those of Medinet Habou, was not cleared out until thirty-one years after Mr. Pennethorne was in Egypt. Until 1864 it was covered by an Arab village. The existence of curves in plan in the columnar alignment at the bases, all convex to the court, and of 1½ inches convexity on each side of the court, is an important point, as an accidental movement could not have occurred at the bases of the columns. My report in the *Architectural Record* continues (p. 462): "Pronounced curves, of 10 inches in one case, appear in the cornice lines, but the cornices have moved forward and the original lean of the centre columns (by which the original constructive curve was increased toward the centre of each side) has been exaggerated by accidental tipping. The joints of the columns have parted at the rear, and it will require careful examination and survey at Edfou to show how much of the upper curve is due to movement of the masonry and how much is due to construction." This report also says: "Although the great court at Karnak is so filled with rubbish that one can climb, in several places, to the tops of the architraves, I am able to announce, as far as these architraves are concerned, that curves convex to the court are visible." This is inconclusive as to accident, and the notes for Luxor are more important, as follows: "Measurements taken by me in all three courts at Luxor show curves in all columnar alignments, at the bases, varying from 1½ to 7 inches" (the measurements being uniform on all sides of a given court and all convex to the centres of the courts).

Another article, having a similar title and bearing on the same subject, but with different matter, appeared in the *American Journal of Archæology,* Vol. X, No. 1, 1895. This is the only article of the three, under the same general title, in which the measures

[a] These temples are now known to be the earlier ones, according to the revised dating of Koldewey and Puchstein.

for the intercolumniations of the Maison Carrée were published. (These will be considered in Chapter VII.)

The amount of the curvature in plan, as measured on the east flank of the Maison Carrée, is 11½ cm., or a little less than 5 inches, in a length of 82 feet. The curvature on the west flank, the side on which the photograph, Fig. 27, p. 43, was taken, appears to the eye to be much greater, and the opinion of the experts who were consulted, as mentioned in one of the following certificates and as implied in the other, was that accidental movement has augmented the curve on this flank. Including its elevation on the high platform, or podium, the height of the Maison Carrée is as great as that of the Parthenon, although its size is so much smaller. Therefore, in measuring the curve it was found necessary to employ workmen accustomed to repairing roofs. These scaled the building by knotted ropes hung from the roof, and after securing themselves beside the cornice by iron hooks and a body belt, were able to drop plumb lines from three different points (the angles and centre) to the pavement below. The amount of deflection was then measured on the pavement. These measurements were taken with the assistance and coöperation of M. Auguste Augière, architect-director of public works for the city of Nîmes. M. Augière's predecessor in the same office, M. Eugène Chambaud, had also a very exact knowledge of the roof and cornice masonry of the temple, having personally inspected the joints of the cornice during the repairs of the roof which he had superintended. His verdict on the subject of the cornice masonry is therefore of decisive importance.

The certificates of these architects follow here. Portions of the certificates containing approval of my views as to the perspective effect of the curves are omitted, as the questions of fact are the only essential ones and the optical effect of convex curvature is universally conceded by experts in perspective:

> "Les mesures ci-après[a] ont été prises avec l'assistance de M. Augière, architecte de la ville de Nîmes. Il constate avoir observé les courbes avec M. Goodyear, et il constate qu'il n'y a pas eu poussée dans la corniche du côté ouest. . . .
>
> "AUGUSTE AUGIÈRE,
>
> "Architecte-Directeur des Travaux Publics de la Ville de Nîmes,
> Professeur d'Architecture et de Perspective à l'École des Beaux-Arts.
>
> "Le 20 février, 1901."

> "Le soussigné, Eugène Chambaud, architecte de la ville de Nîmes, en retraite, après avoir examiné avec M. Goodyear les lignes courbes de la Maison Carrée, a constaté l'existence des dites lignes, comme étant dans la dite construction; toutefois avec la réserve que la courbe de la corniche du côté est a été exagérée par une poussée de la toiture, mais aussi en constatant le fait qu'il y a une courbe aussi de ce côté dans la construction originale, en vue du fait que la ligne des bases des colonnes est courbe de ce côté, comme sur les autres, et qu'il

[a] The original certificate was written on the leaf of the note-book containing the original measurements.

**Fig. 46. Interior of the Chapel Dome, Columbia University.**

Showing the optical effect of concave lines in plan to be, when below the eye, a curve in elevation rising toward the **centre;** and when above the eye, a curve in elevation descending toward the centre. The opposed effects result from convexity. Reproduced from the "Brick-builder," by courtesy of the Editors.

n'y a pas poussée dans la ligne des bases; en vue aussi que la poussée est loin d'être assez grande pour avoir produit la courbe de la corniche. . . . Les joints de la corniche du côté de l'ouest, ou il y a une courbe de onze centimètres et demi, mesure de M. Goodyear, sont parfaits, avec une seule exception, qui n'est pas importante pour la question de la courbe.

"E. CHAMBAUD.

"Nîmes, le 23 février, 1891."

[3] In order to be quite just to Mr. Sturgis it appears desirable to quote the entire passage in which this reference occurs, as follows: "In the case of the Greek monuments these curves have the obvious effect of preventing any appearance of sagging in the epistyle—*for a long straight line above the eye tends to seem curved downward in the middle;* and the top of the stylobate may be thought to have been so built to harmonise with the under surface of the epistyle. On the other hand, though these refinements of buildings have received special attention of late years, there are those students who think them sufficiently accounted for by the desire that every careful builder of artistic, rather than formalised, habit of mind would feel, to avoid the rigidity of perfectly straight lines, mathematically correct and exact."

This volume was published in 1906, a year before my publication on the curves at Cori (see p. 47), which connected with an account of their discovery an analysis of the curious origin and utterly mistaken point of view of the debated error as to sagging horizontal lines.

The quoted passage in the *History of Architecture* concludes with a reference to similar matters as considered in the volume for Romanesque architecture. In this volume Sturgis accepts without qualification (Vol. II, pp. 296–7) all the results of my mediæval research, as obtained in Italy in 1895, and as subsequently published in the *Architectural Record* during the years 1896–7–8. We may conclude that, in his earlier volume, Sturgis felt bound to include an explanation, without giving full assent to it, which he knew to be widely accepted, and which he did not know to be without optical authority.

[4] If the illustration (Fig. 46) of the interior of the dome of Columbia University Chapel (by Messrs. Howells & Stokes) be examined, it will be observed that the concave curve in plan below the standpoint of the camera (and of vision) appears in the picture as a rising curve in elevation, whereas the concave curve above the eye appears as a downward curve in elevation. In such a picture we discount these optical appearances into the facts, but in all cases where the bulge or the concavity is overlooked, and sometimes when it is not overlooked, in the actual building as distinct from a picture, the optical effects are as stated and as they actually appear in this illustration.

The convex curve in plan has an opposite effect. Above the eye it appears to be a rising curve in elevation. Below the eye it appears as a curve in elevation which descends from the extremities toward the centre.

One does not require to be an expert in optics to appreciate these facts. They become obvious to any one by a little experimental observation or by a moment's reflection. For instance, as regards the optical effect in elevation of a convex curve in plan above the level of the eye, let it be imagined that we are standing opposite the centre of a long, flat rectangular screen, and that this screen is gradually bulged forward toward the centre; it is evident that its upper line will begin to rise in appearance toward the centre, because the part of the screen which is nearest the eye necessarily appears larger, and consequently higher, than the ends, which are more remote.

The illustrations of the Maison Carrée and of the court at Medinet Habou (Figs. 22, 28, pp. 34, 45) show by dotted lines the optical effects of curves in plan above the eye and convex to the standpoint of vision. These drawings give the effect for an angle of 45°. It is important to remember that these optical effects of curves in plan increase very much as one approaches nearer than the standpoint where the angle of vision is 45°, and that they decrease when one recedes from that standpoint. It is only on the level of the eye that the curve in plan, whether concave or convex, appears to be a straight line.

[5] The theory of Thiersch, briefly stated, starts from the illusion which tends to affect the appearance of two lines meeting at an angle. These effects were cited by Penrose for acute angles, as calling for a correction under the gable. Thiersch, however, points out that, whereas acute angles appear larger than they really are, obtuse angles appear smaller.

His arguments contend that the direction of Vitruvius regarding the construction of the curves was limited to those temples which stand on an elevated platform above the level of the eye (a podium). Thus the Parthenon (which is also raised above the level of the surface approach), as seen by a spectator looking toward one of the angles, exhibits obtuse angles both in the stylobate and in the entablature, with the apex of the angle turned toward the spectator. Fig. 47, p. 77, illustrates the appearance of these obtuse angles in the platform and entablature from such a point of view as is assumed by Thiersch. According to his theory these angles appear smaller than they are, and as this effect decreases with the distance from the angle, the lines appear to curve downward away from the angle. This effect would be corrected by a rising curve in elevation.

Hauck contested this explanation on the ground that the optical deflection of the obtuse angle is so inconsiderable that a correction would not be needed, but more particularly because such a correction would, in any circumstance, be needed only for the spectator looking up toward the angles of the building, and would not be needed in views facing the front or sides.

Hauck based his own theory on the fact that the intercolumniations of the Parthenon are smaller at the angles by about two feet, in order to admit of placing the corner triglyphs at the angles of the building, instead of placing them over the centres of the angle abaci, where they would normally appear. (See Chapter I, p. 20, and Chapter VI, p. 186.) This diminution of spacing causes an increase of perspective effect from the point of view facing any side of the temple, from positions nearly opposite the centre, and this increase of perspective effect is farther accented by the gradual diminution (of about four inches) in the widths of the metope spaces in the direction of the angles. Hence, according to Hauck, if the rising curves in elevation, due


**Fig. 47. The Parthenon.**

From a point of view showing the obtuse angles considered by the theory of Thiersch.

to normal perspective, were not also correspondingly increased, the perspective effect of the columns would be out of harmony with the perspective effect of the horizontal lines.

Thus Hauck, in a sense, returned to the explanation of Hoffer. For although he held that perspective exaggeration, for its own sake, would not have been in line with Greek feeling, he also held that this perspective exaggeration was properly sought, in view of the contradictory effects otherwise produced by the narrowing of the angle intercolumniations.

As the title of Professor Hauck's monograph indicates, he supposed that the Greek curves were confined to the Doric style, for it was only in this style that the angle intercolumniations were reduced in order to allow the triglyphs to be placed at the angles of the temple. Since the date of his publication, the discovery of curves in the Ionic temples at Pergamus and Messa (see p. 125) would have vitiated his theory, but it is also wholly unavailable for the curves at Medinet Habou. It may also be remembered that the directions of Vitruvius about the curvature *referred to Ionic temples.*

So far as the theory of Thiersch is concerned, the openings of the obtuse angles in the interior of the court at Medinet Habou are turned toward the spectator, not away from him (as in the exterior of a Greek temple). The angle illusion, if any were produced, would therefore be a rising curve in elevation, and would thus need no correction.

Although the theories of Thiersch and Hauck are no longer tenable, their publications still have very great interest and importance as critiques of the theory of Penrose and for questions of optics as related to architecture.

The theory of Thiersch is the most elaborate effort which has ever been made by an optical expert to explain the reason which is given by Vitruvius for his direction that the temple platform should have an upward curve, but the explanation which is offered in text (p. 58) is a much simpler one, and appears to solve all difficulties as far as the comprehension of Vitruvius in the matter of the stylobate is concerned. It is evident, however, that the Vitruvian explanation is still insufficient, as not being applicable to the entablatures. Vitruvius may have supposed that the curve of the entablature simply followed the curves of the steps, but Penrose has already pointed out the error of this possible supposition, because the entablature of the Propylæa is curved, while the steps are straight. See page 3 of his work.

[6] *Kunstgeschichte des Altertums,* p. 207. Leipzig, Weigel, 1871. As noted on p. 6, this passage is omitted from the English translation. Reber's explanation is so fanciful and far-fetched that it hardly needs to be quoted, were it not for the fact that it recognises the constructive existence of the concave curvature of the Parthenon, and that it again verifies the point that optical experts have always recognised the natural effect of a straight horizontal line above the level of the eye to be one bending downward toward the extremities (and not bending down toward the centre, as so frequently and erroneously supposed). Reber held that, because the concave curve in plan produces the optical effect of curving downward toward the centre, it was intended to "paralyse" the effect of the constructive rising curve in elevation, on near approach,

because the normal perspective curving effect would otherwise appear overdone. This explanation could not apply to Cori, where no rising curve in elevation has been found. Our next chapter will offer much more satisfactory explanations of the Greek curvatures than the hair-splitting hypotheses which form the necessary topic of this one. It appears to me certain that the correct explanation of the concave curvature has been given by Michaelis, as quoted from his own text in the following chapter.

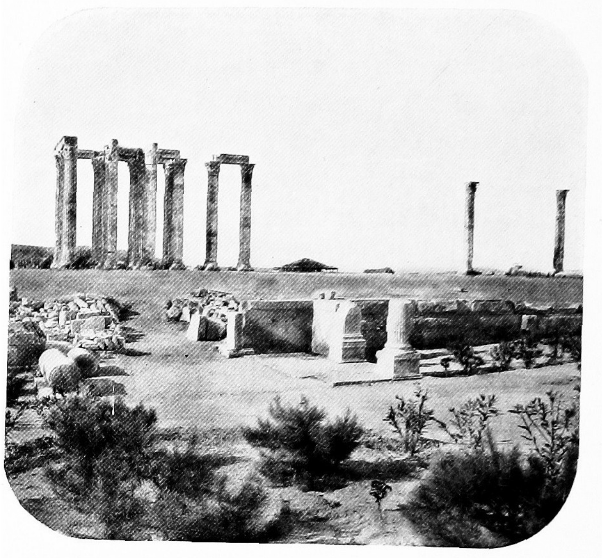


Fig. 48. Temple of Olympian Zeus, Athens.

# CHAPTER THREE

## THE ANCIENT HORIZONTAL CURVATURES CONSIDERED AS TEMPERAMENTAL REFINEMENTS

## THE GREEK ENTASIS

Fig. 49. The Parthenon, West Front and North Side.

# CHAPTER III

## THE ANCIENT HORIZONTAL CURVATURES CONSIDERED AS TEMPERAMENTAL REFINEMENTS

We have seen (p. 3) that the earliest published announcement of the Greek curvatures was that of Joseph Hoffer, who was at the time in official charge of the Athenian ruins, and that his related publications appeared in the "Wiener Bauzeitung" for 1838. Although Hoffer made a suggestion which has rarely met with the approval of other critics—viz., that the rising curvatures in elevation were intended to exaggerate the effects of normal perspective[a]—he otherwise expressed himself with warm enthusiasm as to their æsthetic and artistic significance. The following passage has great interest as being absolutely the first critical appreciation ever published on this subject:[b]

> In modern times great porticoes, of at least equally large dimensions, have been built, and yet we have not been able to achieve the same satisfactory effect. The cause is made clear by a close study of the ancient ruins, and we find then that the Greeks were not content to build their temples according to narrow rules or according to such a canon as Vitruvius, or the modern architects, endeavor to establish, but that everything was with them a matter of feeling.[c] They had the feeling, which was encouraged by their high culture and their happy climate, that straight lines have a *cramped and stiff effect.*[d] They saw that Nature avoids the rectilinear and develops its most attractive forms in swelling curves, and so they endeavored to make the construction of their buildings resemble Nature, to transfer to them the beautifully curving forms which surrounded them, and thus to infuse the lifeless forms of art with a breath of living Nature. Thus were their temples of worship built, and thus we find in them a system of curving lines whose perfect logic fills us with wonder and astonishment at the refinement of feeling which they express.

It is the purpose of this chapter to show that the most distinguished art historians of Europe have either followed and repeated, or independently suggested, these views of Hoffer, with only slightly varying phraseology, and that even in the great work of Penrose there is abundant occasion to

[a] See passage quoted at p. 57.

[b] No. 41 of the quoted journal, p. 370. Tr. by W. H. G.

[c] It will be observed that this point bears on the first title of this work: "Studies in *Temperamental Architecture.*"

[d] "Einen beengenden und starren Eindruck."

point out that he was not insensible to the æsthetic beauty and effective artistic results of the Greek horizontal curvature. On the other hand, it is of great significance that, aside from the refutations which the Penrose theory of the Greek curvature, as an optical correction, has experienced,[a] a no less adverse criticism of this theory of optical correction has been offered by the silence and complete reserve regarding it which have been exhibited by the distinguished art historians to be presently mentioned.

All of them quote Penrose and, in the main, wholly depend on him *for their facts.* All of them avoid debating his theories, and, without an open expression of dissent, quietly pass them by and range themselves on the side of the opinion which Hoffer had first expressed, viz., that the Greek curvatures were inspired by feeling and by the sentiment of beauty; in other words, that they were temperamental refinements.

It results, however, from the encyclopædic aims and character of the great German histories of art that their references are brief and without controversial documentation. This would have been fatal to that brevity of reference to special subjects which was demanded by the wide scope of these books.

In the order of time and following the appearance of the great work of Penrose in 1851 (very little had appeared on the subject between 1838 and that year[1]),[b] we may first mention and quote the opinion of Franz Kugler (1808–1858). Lest my own views of his distinction should appear exaggerated, the statement of another author may be quoted for the fact that in his two-volume "Handbook of Art History" (1841),[c] "he projected, for the first time in Germany [that is to say, in Europe], a complete account of the history of art down to modern times."[d]

Kugler was, in fact, the father of that compendious and critical treatment of the history of art which was subsequently enlarged and specialised by his great contemporaries. Considered as encyclopædic and critical compendiums, his books are still unrivalled. His two-volume history of art, just quoted, was the forerunner and prototype of Lübke's more popular and somewhat briefer, but also less successfully balanced, "History of Art," which has had such great vogue in its English translation. His four-volume "History of Architecture"[e] is to-day the only extant encyclopædic compendium of architectural history, as distinct from other works which do

[a] The entire matter of Chapter II is devoted to this subject.

[b] The numbered references refer to the Appendices at the end of the chapters.

[c] *Handbuch der Kunstgeschichte*, 5th edition. Stuttgart, Ebner und Seubert, 1872.

[d] *Lexikon der Bildenden Künste*, von Dr. Herm. Alex. Müller. Leipzig, Verlag des Bibliographischen Instituts, 1883.

[e] *Geschichte der Baukunst.* Stuttgart, Ebner und Seubert, 1856–1867.

Fig. 50. Curves in Elevation of the Stylobate, East Front of the Parthenon.
From a Stillman photograph belonging to the Architectural School of Columbia University.

not aim at practically universal mention of the monuments. His four-volume "History of Painting"[a] is to-day the best work of the given dimensions and scope, and is well known in English translation.[b] Kugler's characteristics were precise expression, encyclopædic mention, just critical appreciation, systematic arrangement, and great brevity of style.

This authority said of the Greek curvature, in his "History of Architecture" (1856, Vol. I, p. 199):

It was the purpose of Greek art to relieve the whole mass of the building from an appearance of oppressive weight. This effect was obtained by giving a slight upward curve, or swell, to the main lines of the platform in place of rigid straightness. Without being noticeable to the eye, this curvature gives, notwithstanding, *an effect of breathing life* to this portion of the construction. The great lines of the entablature, especially those at the ends of the building, have also, in some of the finest monuments, a similar but more delicate curve.[2] This appears to have had reference to the sculptures which are carried by the entablature, especially the statuary groups of the gables, whose weight likewise required a slight elastic counter-resistance.

A foot-note to this passage mentions that the facts are to be found in Penrose, but that the explanation is Kugler's own matter, thus quietly passing by the Penrose theory as to the optical correction of an optical depression under the gable.

We turn next to Carl Schnaase (1798–1875). His eight-volume "History of Art," which he did not live to carry beyond the fifteenth century, but which is comprehensive and encyclopædic down to that time, appeared between the years 1843 and 1864, inclusive.[c] This work is a spirited elaboration, with much greater fullness of detail and of critical appreciation, of the ideal of art history as established by Kugler, to whom his book was dedicated. It was the first and greatest of the more intensive and more detailed histories of art which have been published in Germany (and no other nation has attempted works of the same universal and comprehensive ideal). The lexicon already quoted mentions Schnaase as the "greatest genius among the art historians of the modern time."[3]

Schnaase's second volume mentions the Penrose theory of optical correction as a doubtful one, and adds that "a highly trained eye might obtain an impression [from the horizontal curvature] similar to that made by the curvature of the column; *a feeling of life inspired the whole building,* dispelling its mathematical rigidity."[d]

[a] *Handbuch der Geschichte der Malerei,* 3d edition, 1867.

[b] Kugler's *Italian Schools of Painting.* Revised by Layard. London, Murray, 1900 (2 vols.). Kugler's *German, Flemish, and Dutch Schools.* Revised by J. A. Crowe. London, Murray, 1898 (2 vols.).

[c] *Geschichte der Bildenden Künste.* Düsseldorf, Julius Buddaeus. The eighth volume appeared after Schnaase's death, in 1879.

[d] Second edition, 1866, pp. 51, 52.

We may next mention Jacob Burckhardt (1818–97), who was the greatest modern expert in the general knowledge and general criticism of art in Italy, as well as the highest German authority on the history of Italian Renaissance culture. He was also a general historian of vast attainments and incisive insight. His first published work (1853), "Das Zeitalter Constantins" ("The Period of Constantine"), is the best ever written on that period, and a four-volume work on the history of Greek culture was published after his death. As a historian Burckhardt is, however, more widely known as the author of the "Kultur der Renaissance in Italien" (1860), which is the ablest extant condensed philosophic treatise on that subject.[a]

As an art historian he was the author of "The Cicerone" (1855), which ranks as a unique and authoritative guide-book to Italian art. Its criticisms are of the most pithy, incisive, and reliable character. The book is recognised by all experts as equally indispensable to the most advanced specialists and to the most amateur students of Italian art. The criticisms and appreciations of Taine's "Italian Journey" are largely based on "The Cicerone," and this fact is formally mentioned in Taine's preface.[b]

After Ranke's death in 1872, Burckhardt was invited to fill his chair of history in the Berlin University, but he declined the invitation. He was at different times intimately associated in Berlin with Franz Kugler (the father of modern compendious art history). He edited in Berlin (1846–48), at Kugler's request, the new editions of his "History of Painting" and of his "Hand-book of Art History."[c] At a later date, after Kugler's death, the fourth volume of Kugler's "History of Architecture"—that on the architecture of the Renaissance (1867)—was written by Burckhardt for Italy, while the section for France was prepared by Lübke.[d]

Burckhardt's standing among modern art historians being thus attested, his brief but comprehensive appreciation of the Greek curvature may be quoted as follows from his description of the temple of Poseidon (so called) at Pæstum:

> Perhaps the attentive eye will glance along the various sides [of the temple] and note that there is not a single mathematically straight line on the entire building. At first we shall be inclined to take for granted inaccurate measurements, or the effect of

[a] *The Civilisation of the Renaissance in Italy*, tr. by S. G. C. Middlemore (Sonnenschein and Macmillan).

[b] Only the section of painting has been published in English (*The Cicerone: An Art Guide to Painting in Italy*. Tr. by Mrs. A. H. Clough. Scribner). There is an entire French translation of excellent quality, now in its third edition. The German original is now in its tenth edition, the present editor being Dr. Bode, director of the Berlin Art Museum.

[c] From this latter work the more widely known art history of Lübke was mainly abridged.

[d] Most of Burckhardt's life was spent in Basel, and after 1858 he held a permanent position as professor of history and of art history in its university.

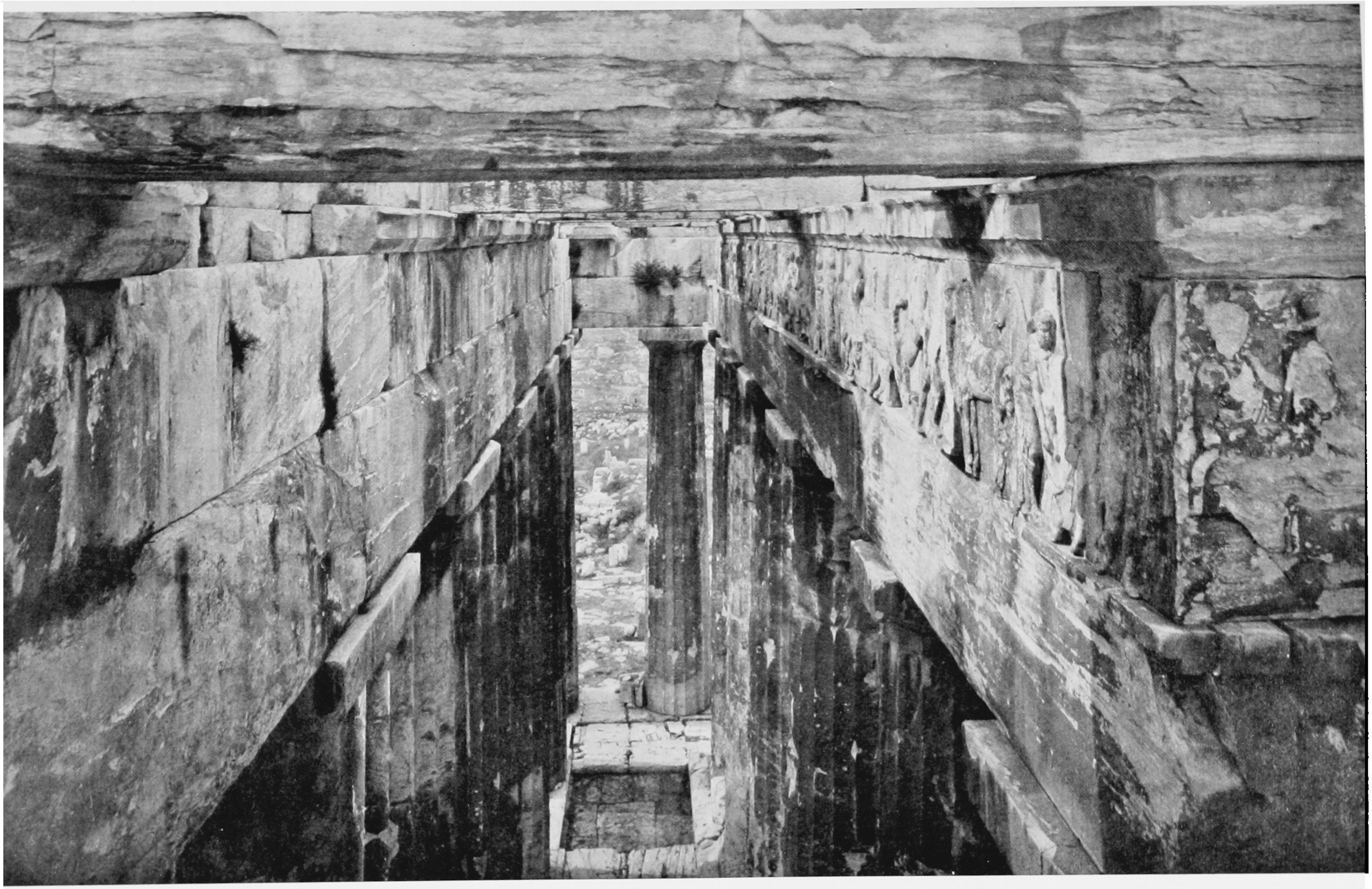


Fig. 51. Curves in Elevation of the Parthenon Frieze, Western Portico; Sighting on the Entablature.

From a Stillman photograph belonging to the Architectural School of Columbia University.

earthquakes, or some similar cause. But whoever stands opposite the right-hand angle of the front side, so that the upper cornice of the flank can be sighted in a foreshortened line, will discover an outward bend of several inches, which can only have been produced by intention.[a] And more things of the same kind will be found. *These are expressions of the same feeling which called for the outward curving of the columns* [the entasis], *and which everywhere sought to give to apparently mathematical forms the pulsation of a living organism.*[4]

In the same sense, and with greater detail, did Adolf Michaelis, professor of classical archæology in the University of Strassburg (born 1836), express himself in his classic and unique work on the Parthenon:[b]

It need not be mentioned that these slight deflections from the rigid mathematical line are not at all, or only slightly, visible to the searching eye, but they are, notwithstanding, apprehended by feeling, as every unprejudiced observer will testify, and in union with the other irregularities they produce that effect of life ("Lebendigkeit") which so remarkably distinguishes the Greek buildings from our own modern architecture, which works by rule and measure. The secret of Nature has been learned, which knows no strictly mathematical line; even the horizontal line of the distant ocean appears slightly curved, a prototype of the temple curves. Perhaps, indeed, there was another effect purposed in the deflections from rectilinear design. No one who visits the Acropolis is unaware of the effect which is produced by the placing of the buildings out of parallel. Not only is the line effect improved, but the manifold effects of light and shade are also multiplied. Now there is hardly a perpendicular surface on the Parthenon: the side walls lean inward, and so do the architrave and frieze, but the latter leans less at the angles than it does in the middle, while the faces of the cornice and antefixes lean forward. The entire entablature is, moreover, slightly concave or drawn in, so that the façade recedes slightly toward the centre, but less on the lower edge of the architrave than at the cornice. However impossible it may be to observe these slight bends of vertical surfaces, as regards the lines, it is all the more certain that they are of value for the fine differences of light and shadow.

The numerous foot-notes to this passage contain frequent references to Penrose as authority for the facts. Thus the discreet avoidance of even a mention of the Penrose theory of correction is extremely significant for the disfavor in which it has been held by Professor Michaelis.

Of great interest is the disposition of this high authority to accept the concave curvature in plan of the Parthenon as a constructive one, especially as the contrary view of Penrose is quoted in foot-note. The opinion of Michaelis that varying effects of light and shadow were obtained, and may have been sought, by the concave curvature is of the highest importance. My own views as to the purpose of the concave curvature in plan coincide with these opinions. Penrose has himself given several instances of the fine effects of profile curvature on the variations of light and shadow, and these are referred to in the foot-note of Michaelis to this passage.

[a] See Figs. 25, 26, pp. 37, 39. For comment by Koldewey and Puchstein, see foot-note, p. 42, and Appendix[1], Chapter II.

[b] *Der Parthenon* (Leipzig, Breitkopf und Härtel, 1871), p. 19.

Among the various French appreciations of the Greek refinements, that of Émile Boutmy may be mentioned as also ignoring the theories of Penrose, while also using his facts. After noting that the forms of the Parthenon are apparently geometrical and regular, he goes on:

> If we approach nearer and look with greater care, we shall find that in all these innumerable straight lines there is not a single one which is really straight. . . . While the general summary impression is one of rigid geometry, the deeper and more intimate impression, which unites with this, and which comes to the senses as though bound up with it, is that of elasticity and of flexible grace. Felt without being perceptible, unknown to the brain while our eyes enjoy the effect, this arrangement arouses no feeling of dissatisfaction and is sufficient to change the rigidity of rectilinear forms into a forcible impression of living, supple firmness.

Boutmy adds to this passage a sentiment of Delacroix which was transcribed by M. Ph. Burty from one of the artist's notebooks: "There are some lines which are monstrous:[a] the straight line, the regular serpentine—above all, two parallels. When man creates them, the elements destroy them. Regular lines are only found in the brain. Thence comes the charm of things which are ancient or in ruins; ruin brings the object closer to nature."[b]

M. Auguste Choisy's opinion on a point of æsthetics and of artistic effect is especially interesting, because he was one of the most distinguished engineers of modern times. Among architectural historians no other writer has had the same weight as a practical expert in engineering construction. Choisy said of the Greek curvature:

> There results from this unaccustomed arrangement of lines a new and strange impression. When not advised [of it], the spectator feels something unusual; when advised [of it], he recognises a delicate attention which delights him; thanks to this refinement, the lines have an air of distinction to which our taste cannot remain indifferent; *the edifice avoids the vulgar appearance of a construction with rigid lines,* it is stamped with a new and unexpected character which perhaps escapes analysis, but which captivates us even when we are ignorant of its true sense and cause.[c]

Among English authorities who have expressed themselves in similar fashion may be quoted the eminent names of William J. Anderson and R. Phené Spiers, whose quotation from Professor Percy Gardner's "Grammar of Greek Art" in their "Architecture of Greece and Rome" (p. 74) not only illustrates their own point of view but also makes it possible to add Profes-

[a] "Il y a des lignes que sont un monstre."

[b] *Le Parthénon et le Génie Grec* (originally published in 1870, under the title *Philosophie de l'Architecture en Grèce*), by Émile Boutmy, Membre de l'Institut, Directeur de l'École libre des Sciences Politiques. Paris, Armand Colin, 1897, pp. 176, 177.

[c] *Histoire de l'Architecture* (1899), Vol. I, pp. 408, 409.

Fig. 52. Curves in Elevation, West Front of the Temple of Poseidon at Pæstum. Brooklyn Institute Museum Series of 1895.

Straight lines have been drawn on the stylobate and abaci in order to show the curvature, which has a deflection on the stylobate of 2 cm., or ¾ inch, in a width of 80 feet, according to Koldewey and Puchstein.

sor Gardner's distinguished authority to this list of references. This passage, which relates to the Parthenon, is as follows (p. 39):

The whole building is constructed, so to speak, on a subjective rather than an objective basis;[a] it is intended not to be mathematically accurate, but to be adapted to the eye of a spectator. To the eye a curve is a more pleasing form than a straight line, and the deviations from rigid correctness serve to give a character of purpose, *almost of life,* to the solid marble construction.

To this list of appreciations may be added that of the most recent "Dictionary of Architecture":[b]

After the discovery of these refinements in Greek art, and before their existence in later work was suspected, various attempts were made to suggest an adequate motive for their introduction. Perspective illusion, that is to say, a desire to give an apparently increased size to the building; the desire to correct that delusion of human sight which makes a horizontal cornice under a gable appear to sag; artistic preference;—all were suggested, but a closer examination of the evidence seems to show that the third is not an accidental but the principal motive. It would seem that the theory of perspective illusion has very little to support it, and the theory of visual correction even less. If, however, we can give a satisfactory reason why a column should have an entasis, that same reason will suffice to account for all the other refinements as yet known to exist, at least in classic work. The only satisfactory explanation of them is that the entasis and other such refinements were introduced from artistic preference, from delight in the abstract beauty which results from their use.

The important authorities cited in this chapter thus concur in the opinion that architectural modulations which may not be distinctly perceived are still optically effective and attractive. In the words of Mr. Ruskin: "Let it not be said, as it was of the late discoveries of subtle curvature in the Parthenon, that what is not to be demonstrated without laborious measurement cannot have influence on the beauty of design. The eye is continually influenced by what it cannot detect; nay, *it is not going too far to say that it is most influenced by what it detects least.*"[c]

We may now appeal even to the work of Mr. Penrose as having expressed similar opinions. For instance, he believed that concurrent motives in explanation of the horizontal curves on the flanks of a temple were "a greater appearance of strength *and the appreciation of beauty inherent in a curved line*" (p. 105).[5] In explaining the Greek columnar curvature, or entasis, Mr. Penrose also alludes to *"the real monotony of a perfectly straight line"* (p. 107).

As bearing on the objection sometimes made, that refinements which are not seen by the eye cannot have an effect of beauty, we may again

[a] This direct reference to temperamental considerations is interesting.

[b] "Refinements in Design," by G. L. Heins, in the *Dictionary of Architecture and Building,* by Russell Sturgis, A. M., Ph. D. 3 vols. Macmillan, 1901–2.

[c] *The Stones of Venice,* Vol. II, Chap. v, p. 120.

quote Mr. Penrose for the fact that "the hardness and dryness" which he says are perceptible in modern copies of the Greek temples are due to the absence of the Greek refinements. For instance, he says: "It has been often noticed that the works of Nature, although usually their tendency is to be symmetrical, are seldom absolutely so; and when in architecture exact symmetry does prevail, a dry effect is not infrequently produced" (p. 11). And again: "It cannot be doubted that those travellers who have wondered that the fronts of the Greek buildings were so much less *dry and hard*[a] than our imitations of them, must have felt, however unconsciously, the beauty of the horizontal curvature" (p. 33). In speaking of the Erechtheum entasis, Mr. Penrose says that it "is confessedly productive of the impression of beauty," and that as it is "scarcely more than two thirds as great as that of the stylobate of the Parthenon, *we cannot deny that the curvature of the horizontal lines may produce some optical effect of beauty*" (p. 33).

As another instance of the appreciation by Mr. Penrose of the fact that certain irregular arrangements in Greek architecture are contributory to an effect of the picturesque, we may also quote the following:

Fig. 53. North Porch of the Erechtheum.

Before quitting the general plan of the Acropolis it will be well to observe the remarkable absence of parallelism among the several buildings. Except the Propylæa and the Parthenon, . . . no two are parallel. This *asymmetria* is productive of very great beauty; for it not only obviates the dry uniformity of too many parallel lines, but also produces exquisite varieties of light and shade. One of the most happy instances of this latter effect is in the temple of Nike Apteros in front of the southern wing of the Propylæa. The façade of this temple and the pedestal of Agrippa, which is opposite to it, remain in shade for a considerable time after the front of the Propylæa has been lighted up; and they gradually receive every variety of light, until the sun is sufficiently on the decline to shine nearly equally on all faces of the entire group.

[a] Italics by Penrose.

**Fig. 54.** Curve in Elevation, Stylobate of the Temple of Poseidon at Pæstum, East Front. Brooklyn Institute Museum Series of 1895.

A straight line has been drawn on the upper step in order to show the curvature, which has a deflection of 2 cm., or ¾ inch, in 80 feet.

***A similar want of parallelism in the separate parts is found to obtain in some of the finest mediæval structures,*** **and may conduce in some degree to the beauty of the magnificent Piazza of St. Marc at Venice. (Page 4.)**

Before summarising the conclusion which would appear to be established by the foregoing quotations, it appears desirable to include in the matter of this chapter some brief consideration of the Greek columnar vertical curvature, or entasis. In the case of the Parthenon the maximum of

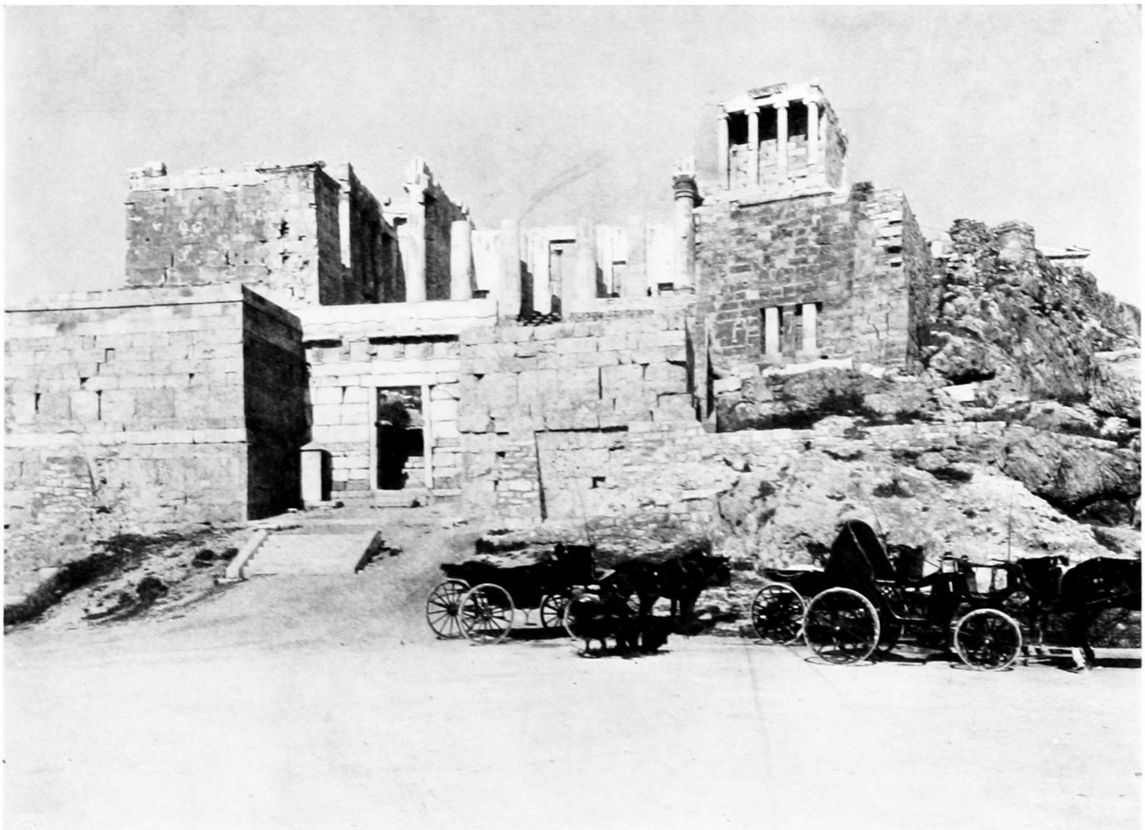


**Fig. 55. The Propylæa and the Temple of Nike Apteros.**

the curve amounts to about two thirds of an inch at about two fifths of the height (approximately thirty-two feet). It is generally agreed by optical experts that a free standing column (not an engaged column) appears thinner at the centre if the sides be straight. The entasis has, among other purposes, that of correcting a resulting appearance of weakness.

It is held by the distinguished optical expert Thiersch, in his quoted essay (see p. 62), that this effect of attenuation at the centre is confined to columns which have a diminution, and that it is not found in columns or round piers with straight parallel sides. On this head, Thiersch appeals to the contrast of mediæval examples with straight sides, and without diminution, as not appearing thinner at the centre.

It is likewise agreed by the best authorities that the entasis gives an appearance of elastic strength and vitality to the column, and that it also had this purpose. All the authorities quoted in this chapter have expressed themselves to this effect, but it has not seemed necessary to quote their

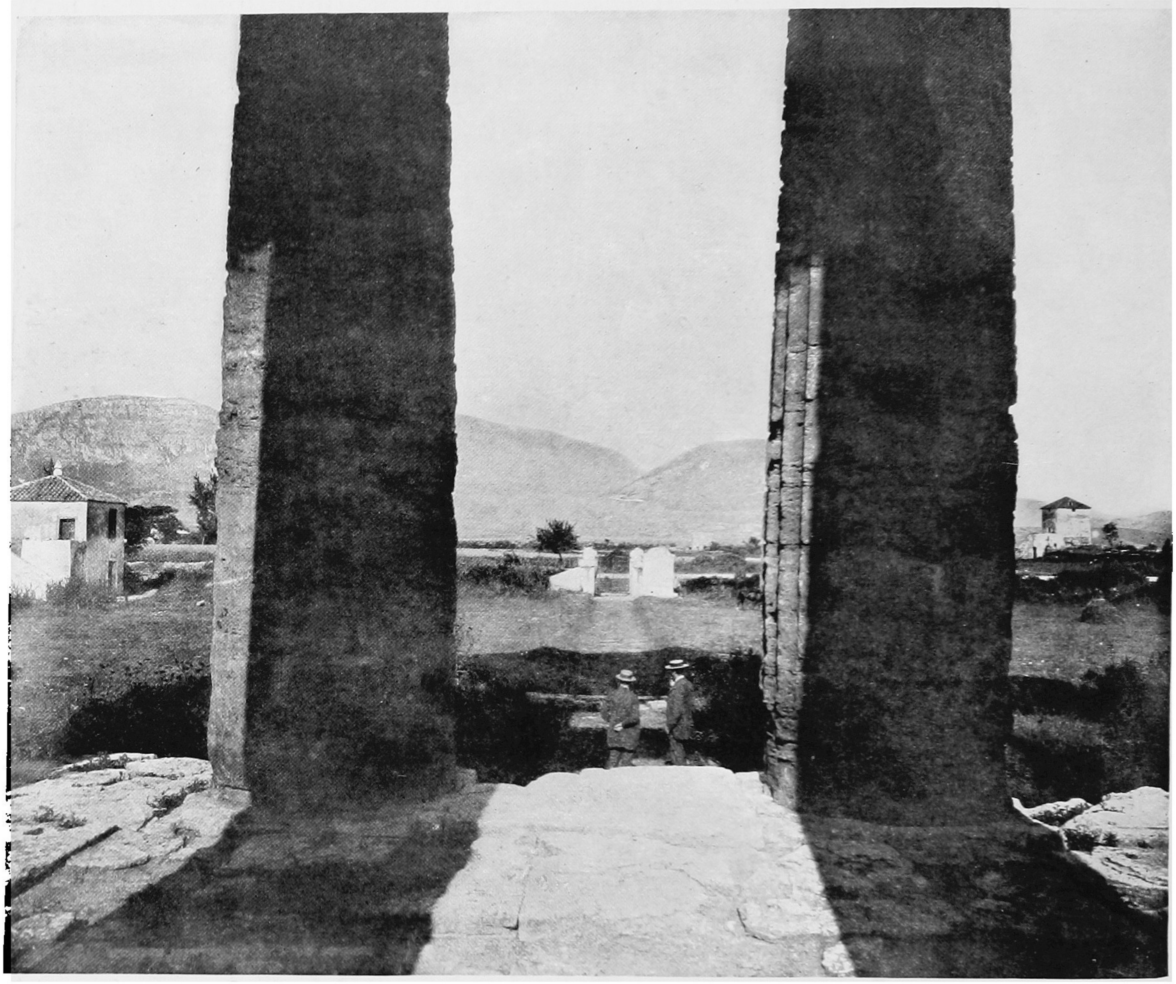


Fig. 56. The Entasis at Pæstum. Columns of the East Front, Temple of Poseidon.
Brooklyn Institute Museum Series of 1895.

views about the entasis in detail. These views are sufficiently suggested by their opinions as to the purpose of the horizontal curvature, which is frequently referred to by the authors of the quoted passages as being of the same character as the entasis.

Moreover, the most inexperienced observer has only to compare the effect of modern classic columns having straight parallel sides with those which are slightly curved in order to realise the advantage of this device.

In the article on the "Entasis" in the Macmillan "Dictionary of Architecture," which is signed by Russell Sturgis, we find this passage: "It appears that an effect which is agreeable to the eye, without further explanation of its remote cause, is enough to account for the free use of the entasis among builders who are following natural and wholesome tradition."

That Mr. Penrose did not confine his explanation of the entasis to the purpose of optical correction will be apparent in the quotations which have appeared in the text of this chapter. As to an effort which is sometimes made to confine the explanation of the entasis to the correction of an apparent optical diminution at the centre of the shaft—a tendency which Dr. Sturgis has justly criticised—it should be remembered that the optical effect of diminution at the centre is admitted to be confined to columns which are seen surrounded by the atmosphere, and, therefore, that the explanation based on the purpose of optical correction could not apply to the frequent Roman and Renaissance use of the entasis in engaged columns. The fine effect of Palladio's palaces at Vicenza appears to be largely due to this latter use.

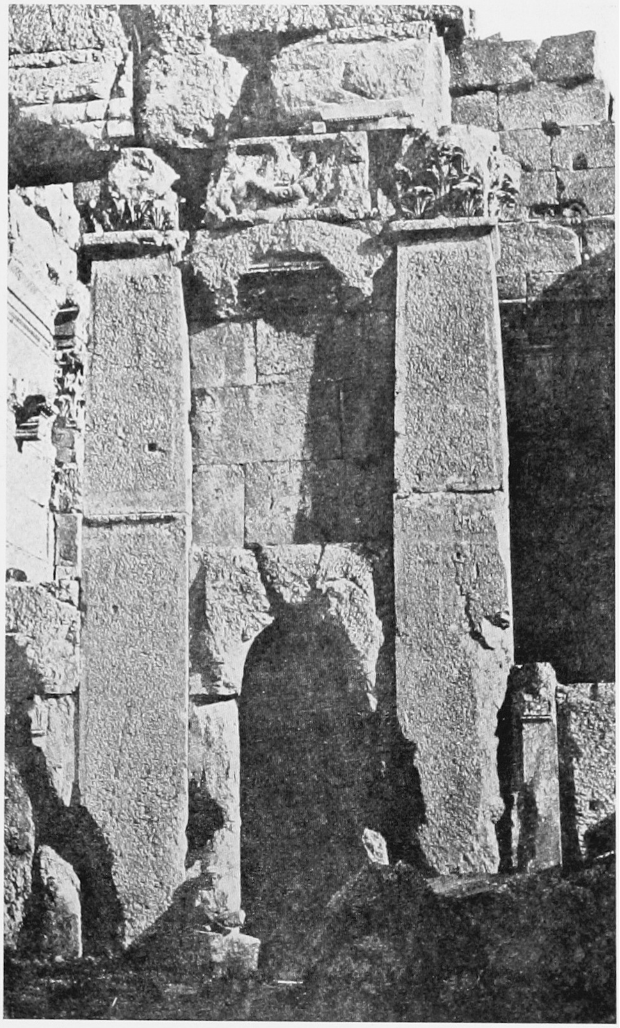


Fig. 57. The Entasis in Roman Pilasters, Baalbek Acropolis. Second Century A.D.

The Romans are generally supposed not to have used the entasis in flat pilasters, but examples of this use appear in the inner decoration of the Acropolis walls at Baalbek, and a photograph of these pilasters has been in my possession since 1869.[a] The Italian Renaissance use of the entasis in flat pilasters must therefore be derived from Roman ruins in Italy which have disappeared since the sixteenth century. The classic use of the entasis in pilasters, as attested

[a] Published in the *Architectural Record* (1897), Vol. VII, No. 1, p. 95, and in Fig. 57.

by the example at Baalbek, proves beyond debate that the purpose of the entasis was something more than the correction of an effect of attenuation at the centre of the shaft, because no such effect occurs in engaged pilasters.

The Greek entasis never bulged, as it frequently does in modern monuments and especially those of the late Renaissance or of quite recent date. In other words, the vertical curvature, as found in Greek use, never exceeded the diameter at the base. On the contrary, the Greek columnar entasis is connected with a gradual diminution of diameter from the base up. It is also a highly important phase of the Greek entasis that it is strongest at about one third or two fifths of the height. Modern columns in which the greatest strength of the curve appears at the centre, or even above the centre, are frequently seen, especially in very recent work, and have a most distressing appearance. This defect also appears in Fig. 57 and is there explained by the decadent period to which the Roman art at Baalbek belongs.

The entasis appears to have been generally employed in the Egyptian obelisks, and thus to have originated in Egypt, but no measurements and no systematic or careful examination of the Egyptian entasis have ever been published. There are, however, various scattering but trustworthy references to the existence of this Egyptian entasis, from which that of Thiersch may be selected, as being from a wholly trustworthy authority. The Egyptian entasis is mentioned by him on p. 18 of his quoted essay (see p. 62).

From the argument of the last chapter the conclusion was drawn that the Greek horizontal curves could not have been intended to make the lines look straight. We shall conclude from the quotations of the present chapter that both the Greek horizontal curvature and the Greek vertical columnar curvature were inspired by an æsthetic preference for the curve and by an æsthetic distaste for the straight line, when it could be conveniently avoided. It need not be doubted that the perspective effects of many of the horizontal curves were appreciated and possibly desired, but it can hardly be held that this was the dominant or leading purpose, when all the facts are considered, and especially those recently attested for the use of the concave curvature in plan, which could not have had a perspective purpose, and which must have been intended to give variety of light and shadow.

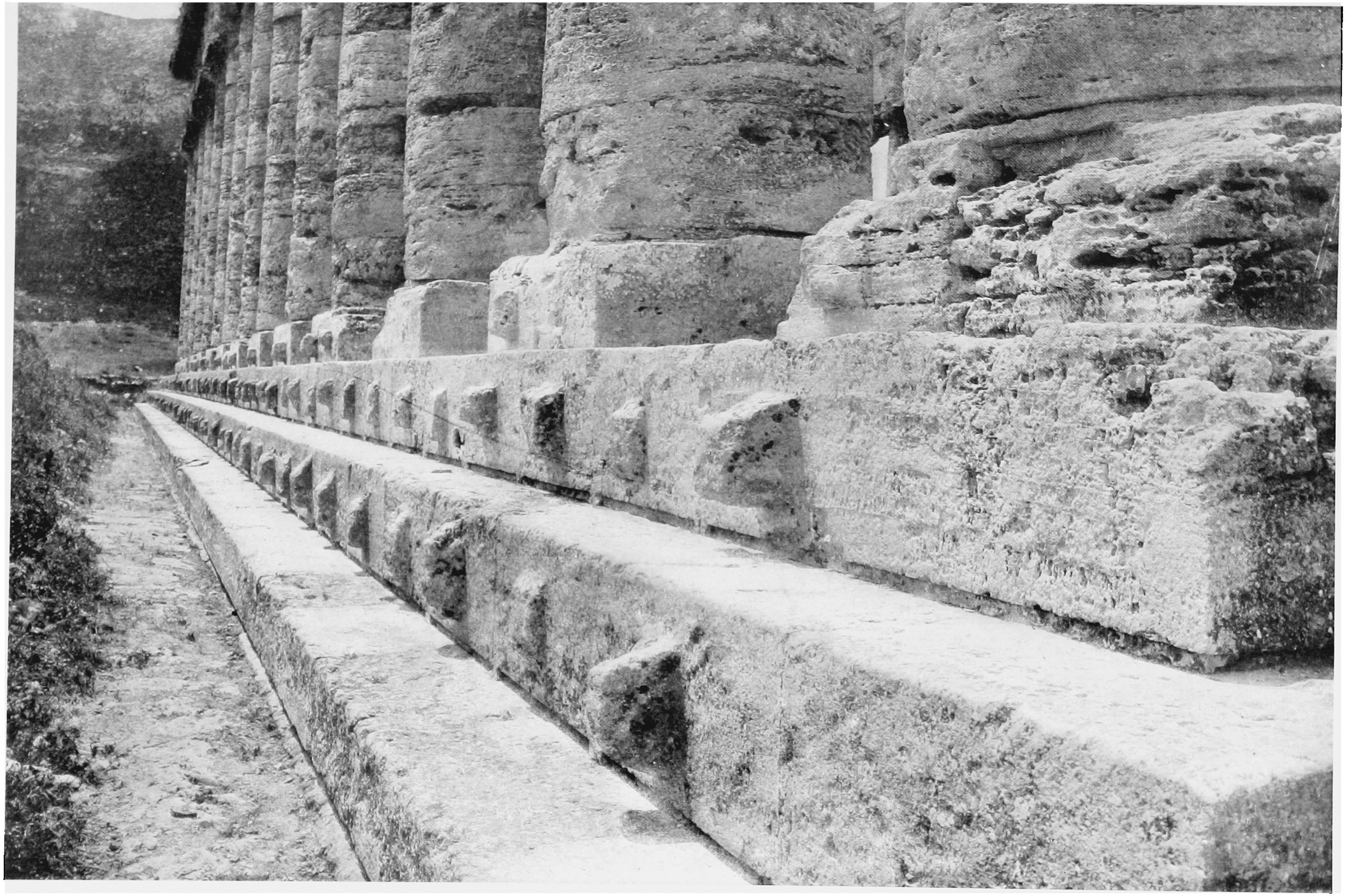


Fig. 58. Curves in Elevation of the Stylobate, South Flank, Temple at Egesta. Brooklyn Institute Museum Series of 1895.
The rising convexity has been measured by Koldewey and Puchstein as being 8 cm., or 3⅛ inches, in a length of 200 feet.

# APPENDIX. CHAPTER III

[1] The German architect Schaubert, who was in Athens during Hoffer's charge of the ruins, made publications on the subject in the *Preussische Staatszeitung* for 1842, No. 355, and in the *Kunstblatt* for 1843, No. 52. These publications are not known to me, and these references are obtained from *Der Parthenon* of Michaelis, who also mentions not having seen them (p. 18). No mention of Schaubert's name is made by Hoffer's publications, although the association of his name with Hoffer's by Penrose and Pennethorne would give a different impression. Neither does either one of them mention that Schaubert's publications, with which they were evidently not acquainted, appeared at a much later date than Hoffer's, which they also evidently had not read.

[2] This sentence implies that some temples have curves in the platform without having them in the entablature, but no such instance is known. The implication found here appears as a more positive statement at p. 234 of the same volume, where it is mentioned that the entablature of the Theseum appears to have had no curvature, and that "at least Penrose has nothing" on the subject. On the contrary, Penrose expressly mentions the Theseum as having curves in the entablature, and specifies their amount, on p. 73 of his book. Kugler's error is probably explained by the fact that the table of measurements which Penrose cites on his p. 27[a] omits to mention the entablature of the Theseum. This is probably because these curves are held by Penrose to have been slightly flattened by accident, and because this table may be presumed to represent only authentic measurements of the original facts.

Kugler's phrase "especially at the ends of the building" appears to be based on the impression of Penrose (p. 104) that the so-called temple of Poseidon at Pæstum has no curves on the flanks. Since Jacob Burckhardt's observations of curves in plan on the flanks, this impression is known to be erroneous. See also p. 126 for the recent discovery, by Koldewey and Puchstein, of curves *in elevation* on the flanks of this temple. In the temple of Corinth the curve is confined to the front of the building, but, generally speaking, both the fronts and flanks of the temples have the curvature, if it exists at all (it is frequently, or occasionally, wholly absent).

Kugler's statement that the lines of the entablature have a more delicate curve than the stylobate is correct as regards the present condition of certain monuments, but this variation is not considered significant by Penrose, who gives reasons of a matter-of-fact character for the slight variations in this particular in the Parthenon and in the Theseum. He thinks that they may be due sometimes to a slight accidental flattening of the upper curves. The variations quoted by Penrose as between the stylobate and the entablature are in the following ratios for the given monuments:

[a] See Appendix [1], Chapter I of this volume.

| | |
|---|---|
| Fronts of Theseum and Parthenon . . . . . . . . . . . | 4:3 |
| Flanks of the Parthenon . . . . . . . . . . . . . . . | 8:7 |
| Flanks of the Theseum . . . . . . . . . . . . . . . . | 10:9 |

[3] This is a close translation of "Der geistvollste Kunsthistoriker der Neuzeit." This verdict appears to slight the greatness of Winckelmann and Burckhardt, not to mention that of Kugler, but it illustrates the high appreciation in which Schnaase's work has been held. It may be said, without qualification, that there is no parallel work to that of Schnaase, of the same scope and dimensions, either in German or in any other language.

[4] "Vielleicht blickt ein scharfes Auge die einzelnen Seiten im Profil entlang und findet dass keine einzige mathematisch gerade Linie an dem ganzen Bau ist. Man wird zunächst an ungeschickte Vermessung, an die Wirkung der Erdbeben und anderes der Art denken. Allein wer z. B. sich der rechten Ecke der Vorderseite gegenüberstellt, so dass er das obere Kranzgesimse der Langseite verkürzt sieht, wird eine Ausbeugung desselben von mehreren Zollen entdecken, die nur mit Absicht hervorgebracht sein kann. Und ähnliches findet sich weiter. Es sind Aeusserungen desselben Gefühls welches die Anschwellung der Säule verlangte und auch in scheinbar mathematischen Formen überall einen Pulsschlag inneren Lebens zu offenbaren suchte." *Der Cicerone*, p. 5. Second German edition, 1869.

[5] The entire passage in which these words occur is worthy of quotation: "We may attribute the use of this additional adjustment [viz., the curvature on the flanks] to the feeling of a greater appearance of strength, *to the appreciation of beauty inherent in a curved line*, and to the experience of a want of harmony between the stylobates and architraves of the fronts and the straight lines used in the flanks of the earliest examples;[a] and further, if we may suppose the first examples of its application on the flanks to have occurred on lofty situations like the Acropolis, the presence of a delicate but not inappreciable curve in what may be considered Nature's great and only horizontal line, the sea-level, may possibly have contributed, with other curves, to suggest its use."

[a] There is no proof for the use of straight lines in the flanks of the earliest Greek examples which have curves on the fronts. Mr. Penrose supposed the so-called temple of Poseidon at Pæstum to be such a case, but was in error on this point. See Appendix[2] of this chapter and p. 126. The temple at Corinth is one instance, but it is the only one known.

# CHAPTER FOUR

## TEMPLES WITH AND WITHOUT CURVATURE
## GAPS IN THE RECORD

## RECENT OBSERVATIONS

Fig. 59. The Theseum, Athens. About 470 B.C.

The curves of the entablature and stylobate on the flank may be sighted by holding the photograph sideways.

# CHAPTER IV

## TEMPLES WITH AND WITHOUT CURVATURE
## GAPS IN THE RECORD

HAVING in the two preceding chapters shown that the Greek horizontal curvatures were not primarily or mainly designed as corrections of optical illusions, and having also shown that Mr. Penrose, who was the original sponsor for this idea, was more than willing to concede the significance of the temperamental element and of the sentiment of beauty as regards these curvatures, it remains to correct an appearance, or disclaim the intention, of slighting the importance of his remarkable book by an over-vigorous criticism of a single one of its features.

The world owes to Mr. Penrose the complete knowledge of the measurements of the Athenian monuments, on which all argument and all controversy relating to the Greek refinements must largely depend, in default of equally exhaustive works on the temples of Pæstum and of Sicily, of which there appears to be no prospect at present.[1] We are thus indebted to this notable authority for the projection and accomplishment of a work of monumental archæologic research without parallel in the modern literature of historic art. Only the measurements by Professor Petrie of the Great Pyramid can vie with those of Mr. Penrose for painstaking accuracy and the complete scientific and mathematical equipment of the author. "The Principles of Athenian Architecture" will endure as long as the famous ruin whose perfection it commemorates and establishes, and its literary style is a worthy and fitting expression of the dignity and monumental character of its subject. That the experts who have differed with its author in the interpretation of many of the facts which he ascertained with such infinite pains are agreed as to the value of his book is illustrated by the tribute of Guido Hauck, who, while differing with it on optical questions, pronounces it to be a "pearl of art-historic literature."

It might now appear to the layman, from the number of quotations and references in the three preceding chapters, that the topic of the Greek refinements had been a prominent subject of modern investigation and interest. This is far from being the case. Among the special publications which preceded or followed that of Penrose, those of Hoffer, which appeared in an Austrian periodical of 1838, are practically unknown and forgotten, and are rarely to be found in the libraries of the English reading world, to say the least. Since the publication, in 1851, of "The Principles of Athenian Architecture," the additions to our knowledge on the subject which it treated have been fragmentary, intermittent, and meagre, and almost wholly due to accidental observations. One of the contributions to expert controversy which has figured largely in the preceding pages —viz., that of Thiersch—appeared in a Berlin architectural periodical which is rarely to be found in libraries outside of Germany, and which is known only to a relatively circumscribed circle of readers even in the country to which the article was addressed. Neither is Hauck's important essay widely known. I cannot mention a single book in which it has been referred to.

Fig. 60. Temple Ruin at Corinth, Sixth Century B.C. Horizontal curvature on the front has been observed by Penrose and Dörpfeld.

As for the appreciations of the Continental art historians which are mentioned in the last chapter, they make an imposing appearance when collated and massed together, but their imposing appearance begins to dwindle when we consider that a research is in question which began over seventy years ago (about 1837), which concerns the most remarkable features of Greek architecture, and that the preceding chapters quote, or refer to, nearly everything that has ever been printed on the subject during all that time, unless the brief and necessarily unsatisfactory references of some popular compendiums were to be mentioned.

Fig. 61. Temple Ruin at Nemea, Fourth Century B.C. The horizontal curvature has been observed by Penrose.

It may hardly be credited, for

Fig. 62. Curves in Elevation of the Entablature, South Flank of the Temple at Egesta. Brooklyn Institute Museum Series of 1895.

A straight line is drawn on the abaci in order to show the curve. For the corresponding curve of the stylobate as measured by Koldewey and Puchstein, see Fig. 58, p. 103.

instance, that the account by Michaelis, consisting of only two pages, from which an extract has been quoted (p. 91), is the longest and most complete general summary of the subject which has ever been printed since the days of Hoffer and Penrose. This, however, is the fact, and if our fragmentary and imperfect knowledge of the general subject is not to appear greater than it really is, these points must be considered.

Fig. 63. Temple Ruin at Sunium, Fifth Century B.C.
The horizontal curvature has been observed by Penrose.

One extraordinary and almost incomprehensible indication of the obscurity in which the contributions of scholars to this subject have been buried is the fate which has befallen the publication of Émile Burnouf in the "Revue Générale de l'Architecture" for 1875.[2] Burnouf announced an obviously correct interpretation of the long misunderstood reference of Vitruvius to the *scamilli impares*.[a] That Penrose in his second edition of 1888, and that Choisy in 1899,[3] should have failed to record this illuminating suggestion is most significant of an almost universal neglect of the subject of the Greek curvature: not because these scholars are supposed to have read everything which appears in serial architectural publications, but because the knowledge of such an important and convincing interpretation would have certainly filtered through to these scholars indirectly, if the habitual readers of the given journal, or its contemporary exchanges, had appreciated the value of the observation and had given it proper currency.

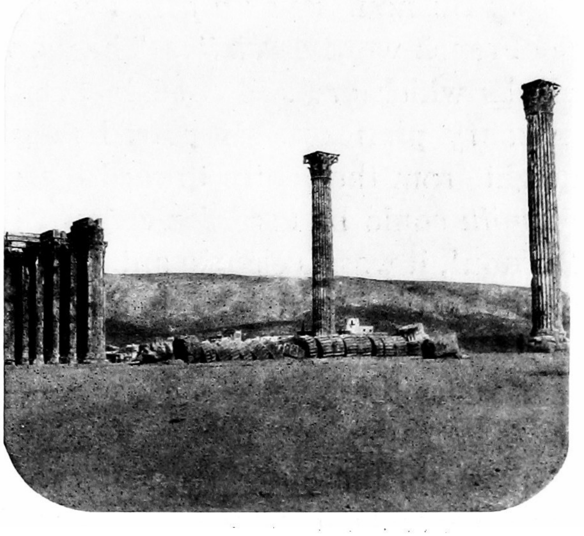


Fig. 64. Temple of Olympian Zeus, Athens.
The horizontal curvature has been observed by Penrose.

A mention of Burnouf's ex-

[a] Appendix[5], Chapter I.

planation of the *scamilli impares* has, therefore, double interest. It shows how the classic curves were constructed (Fig. 65, p. 114), and it also illustrates the neglect with which the Greek refinements have been treated—to the extent that no authority on the given subject has ever republished, or even referred to, this explanation.[4]

Vitruvius directed that the curves of the stylobate were to be constructed by means of "unequal scamilli." Penrose supposed—and his explanation has been followed by all authorities excepting Choisy and including Durm and Koldewey—that the "unequal scamilli" were the drums of the columns which rested on the stylobate.[a] It has been seen that these drums are of unequal height on the opposing sides, otherwise the columns would lean away from the centre of the columnar alignment.[b] This interesting proof of the intended construction of the curves is not, however, the true explanation of the *scamilli impares.*

Burnouf points out that *scamillus* is a diminutive of σκαμνίον ('a little

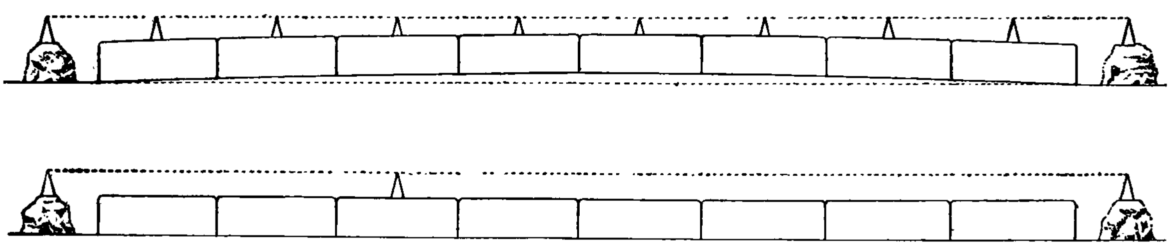


Fig. 65. The Greek Method of Constructing Horizontal Curves by *Scamilli Impares*, as interpreted by Burnouf. From the "Revue Générale de l'Architecture" for 1875.

stool'; Burnouf says *un petit banc*), and may be accurately translated by the French word *nivelette.* These are the small pyramid-shaped sighting-blocks which are still used in France for levelling a line of steps or a masonry platform. If placed in graded sizes, gradually increasing in height from the centre toward the extremities of the line of steps, such *scamilli* could be used for constructing a curve (Fig. 65). According to Burnouf, it was as easy in antiquity to construct a curve with these implements as it is now to build to a level. He also points out that such *scamilli impares* must have been used for building curves in plan.[5]

Besides these various considerations, which show that the subject of the classic refinements has been much neglected, and that the modern literature of the subject is scanty and fragmentary, there is another phase of the general subject which needs to be constantly kept in view, viz., those

[a] See p. 23 of the work of Penrose.
[b] Chapter I, pp. 14, 17, and Fig. 9, p. 17.

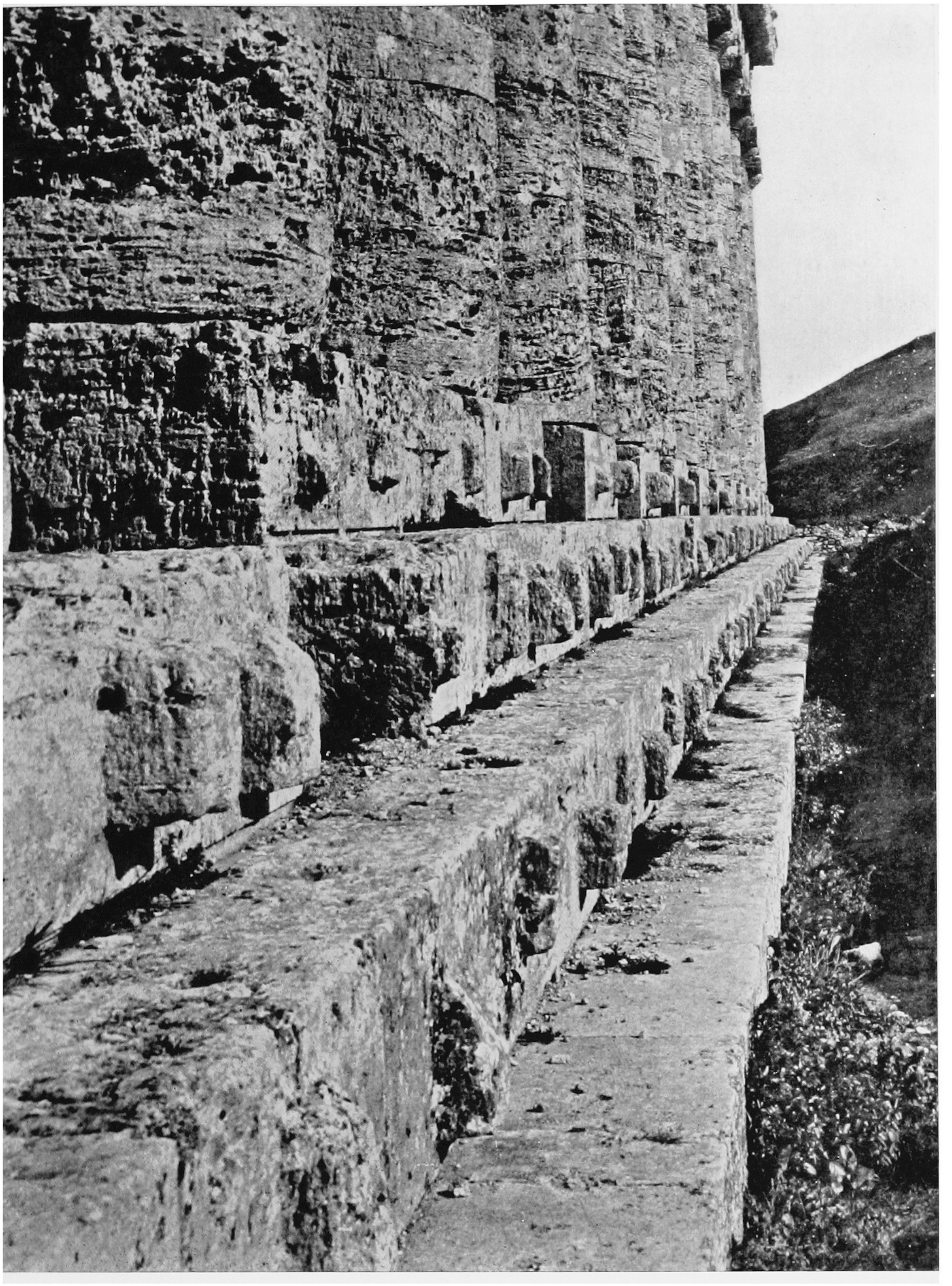


Fig. 66. Curves in Elevation of the Stylobate, North Flank of the Temple at Egesta.

From a photograph belonging to the Architectural School of Columbia University. Compare Fig. 58, p. 103, for the south flank of the stylobate. The rising convexity on the south flank has been measured by Koldewey and Puchstein as 8 cm., or 3⅛ inches, in a length of 200 feet. Compare Fig. 69, p. 119, for the north flank entablature.

limitations and imperfections of our knowledge which are due to the destruction and disappearance of the monuments. It is an unfortunate but natural result of our interest in the surviving monuments that we tend to overlook the enormous number of those which have utterly disappeared, or which are in such a state of degradation and ruin that even an examination of the stylobate for curvature cannot be carried out.

On this head we have first to consider the relatively insignificant number of survivals of temple ruins dating within the limits of Greek history, down to the beginning of the Macedonian period. When we consider the original territory covered by the Greek colonies down to that time, and the great number and importance of the Greek states, as contrasted with the number of extant ruins, it becomes evident that the gaps in the record are a thousandfold greater than the record itself. In the case of hundreds of Greek cities, we have nothing to recall their existence but literary mention, or their coins, and frequently only the latter.

Fig. 67. The Propylæa, Athenian Acropolis. There are horizontal curves in the entablature, but not in the platform, as observed by Penrose.

Add to this consideration another—viz., that in spite of the large territories, long duration, and vast importance of the Alexandrian period, only scant vestiges of its temple architecture remain. Again, for the Roman temple architecture there are hardly half a dozen temple ruins extant in such relative preservation as to allow of any evidence, either negative or positive, relating to the horizontal curvatures or to other refinements. How much greater importance the convex and concave curves in plan might assume if more temples had survived, it is impossible to say. We only know that such curves are much more frequent in mediæval churches than the curves in elevation.[a]

There is still another phase of the general subject which is almost cer-

[a] This reference presumes agreement of the reader with the opinion of the writer that these curves actually exist in mediæval architecture as constructive refinements. This opinion has, of course, been widely contested. See, however, Goodyear in the *Yale Review*, April, 1912; in the *Bulletin of the Brooklyn Institute of Arts and Sciences*, March 4, 18, 1912; in the *American Architect*, December 1, 1909; in the *Journal of the Archæological Institute of America*, Vol. VI, No. 2 (1901); and in the *Architectural Record*, Vol. VI, No. 4 (1897).

tain to escape attention, unless very emphatic stress is laid upon it. *This relates to the known and existing Greek ruins which have no horizontal curvature.*

The Athenian ruins which were known to Penrose as having the curvature, besides the Parthenon and the Theseum, which have been so frequently mentioned in these pages, were the older Parthenon, the Propylæa, and the temple of Olympian Zeus. The only ruins outside of Athens which were known to Penrose *as having the curvature* were those of Sunium, Nemea, Corinth, Egesta, and one of the four at Pæstum.

The temples mentioned by Penrose as *not having the curvature* were the Erechtheum on the Athenian Acropolis, which was begun within eight years of the time when the Parthenon was finished; the temple of Nike Apteros (so called) on the Athenian Acropolis, also of the fifth century B.C.; the temple of Phigaleia, *which was built by the architects of the Parthenon;* the celebrated and relatively well preserved temple of Ægina; and the temple at Rhamnus in Attica. The competent expert who has examined the temples of Zeus and of Hera at Olympia, in this particular, has found no constructive curvature in either building.[6] It has been specifically mentioned by Koldewey and Puchstein, who are the most recent surveyors of the ruin, that it is not found in the so-called Basilica at Pæstum (a sixth-century Greek temple).

Fig. 68. Temple Ruin, Ægina. Fifth Century B.C. This temple has no horizontal curvature.

Among these instances of the known absence of curvature probably those of the Erechtheum and of the temple at Phigaleia (modern Bassæ in the Peloponnesus) are the most striking, especially the latter, because it was built by the architects of the Parthenon. Both Penrose and Hauck have suggested tentative explanations for the absence of curvature at Phigaleia which do not appear convincing. The best explanation for this temple, and for others of the best period which lack the curvature, may probably be that of economy of money and labor. Although considerations of economy would hardly affect the curves of the stylobate when considered by themselves (Burnouf has shown the contrary), the labor and consequent cost of grinding the beds of the lower drums of the shafts, so that they might stand on the rising surface without tipping away from the

**Fig. 69. Curves in Elevation of the Entablature, North Flank of the Temple at Egesta. Brooklyn Institute Museum Series of 1895.**

Compare Figs. 58, 62, 66, pp. 103, 111, 115. A straight line has been drawn on the abaci to show the curve. The curve of the south stylobate has been measured by Koldewey and Puchstein as having a rising convexity of 8 cm., or 3⅛ inches, in a length of 200 feet.

centre (see Fig. 9, p. 17), must have been very considerable. The same point would also apply to the upper drums of the shafts (Fig. 9), on which the entablature rests. As regards the temple of Phigaleia, we must also remember that Arcadia was a very poor province, and that Phigaleia was only a provincial town of that territory. It is said, however, by Penrose that "the actual construction is of the very best quality," and that it was also mentioned for that particular by Pausanias.

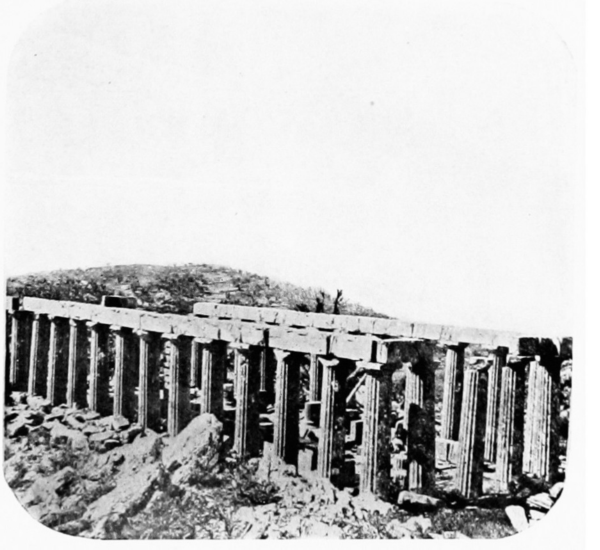


Fig. 70. Temple Ruin at Phigaleia, Fifth Century B.C. This temple has no horizontal curvature.

As regards the Erechtheum, it may be remembered that it was built during the Peloponnesian War, when funds for outlay on Athenian art were not as plentiful as they had previously been. Thus economy might also have been the explanation in that instance. At all events, the facts are there, and they help us to understand why there are no mediæval churches in Italy which rival the cathedral of Pisa and St. Mark's at Venice, either in general importance or in the matter of refinements. There is no doubt that refinements were carried farther in the Parthenon (aside from the curvature) than in most Greek buildings, and there is no doubt that the enthusiastic interest of the entire Athenian state, and the unlimited supplies of money resulting from that interest and from the ascendancy of Pericles, are the main explanation.

Fig. 71. The Erechtheum (Parthenon columns in the foreground). This temple has no horizontal curvature.

Students of Italian mediæval history who know that Pisa and Venice were by far the richest and most powerful Italian states in the eleventh and twelfth centuries may easily understand from the same point of view why their greatest churches occupy such an exceptional position in the study of Italian refinements. There is also a distinct minimising in the variety and subtlety of the Italian mediæval refinements during the late Gothic period. Thus, important cathedrals like those of Florence and Milan appear to have none. In such cases the decadence of artistic taste, or of interest in the Gothic style, and the tendency toward formal regularity, which continued to increase until its final triumph in the Renaissance, appear to be the explanation. It may also be remembered that the relative decadence of Greek art began with the period whose earliest monument is the Erechtheum.

Thus, if this preliminary volume is to be of assistance to later ones on mediæval work, the absence of the curvatures in various known and surviving temples is a matter to be carefully taken to heart, as showing that these and other refinements were far from being of universal use in antiquity. For perhaps the most general and the most unreasonable objections to the results of my mediæval research have been made by those who did not find the given refinements in some church or cathedral with which they happened to be more familiar than they were with the one published.

It is, however, desirable to mention and correct, in this connection, a recent statement that there are no instances of architectural horizontal curves in the Greek Colonies, which runs as follows: "These curves also occur in the Theseum and in the Athenian Propylæa, but not in the temples at Bassæ and Ægina, *nor in the Colonies.* Delicate workmanship, such as was necessary for them, was too difficult to manage in the coarser stone of which these examples are built."[a] The great merit of the work in which this passage occurs makes it the more important to point out that two instances of Colonial curvature were already known to Penrose, viz., the so-called temple of Poseidon at Pæstum, as regards the fronts, and the temple at Egesta. Two instances at Girgenti are illustrated in the next chapter, and the ruins at Messa on the island of Lesbos and at Pergamus in Asia Minor, to be presently mentioned, may also be considered as in Colonial territories, although the latter is of the Macedonian period. Thus we know of six instances outside of Greece and of only eight instances in the mother country, viz., the older and the later Parthenon, the Theseum, the Propylæa, the temple of Olympian Zeus and the temples of Sunium, Nemea, and Corinth.

It is also stated in Professor Simpson's book (p. 92) that "in most of the

[a] Professor F. M. Simpson's *History of Architectural Development.* Longmans, Green & Co., 1905.

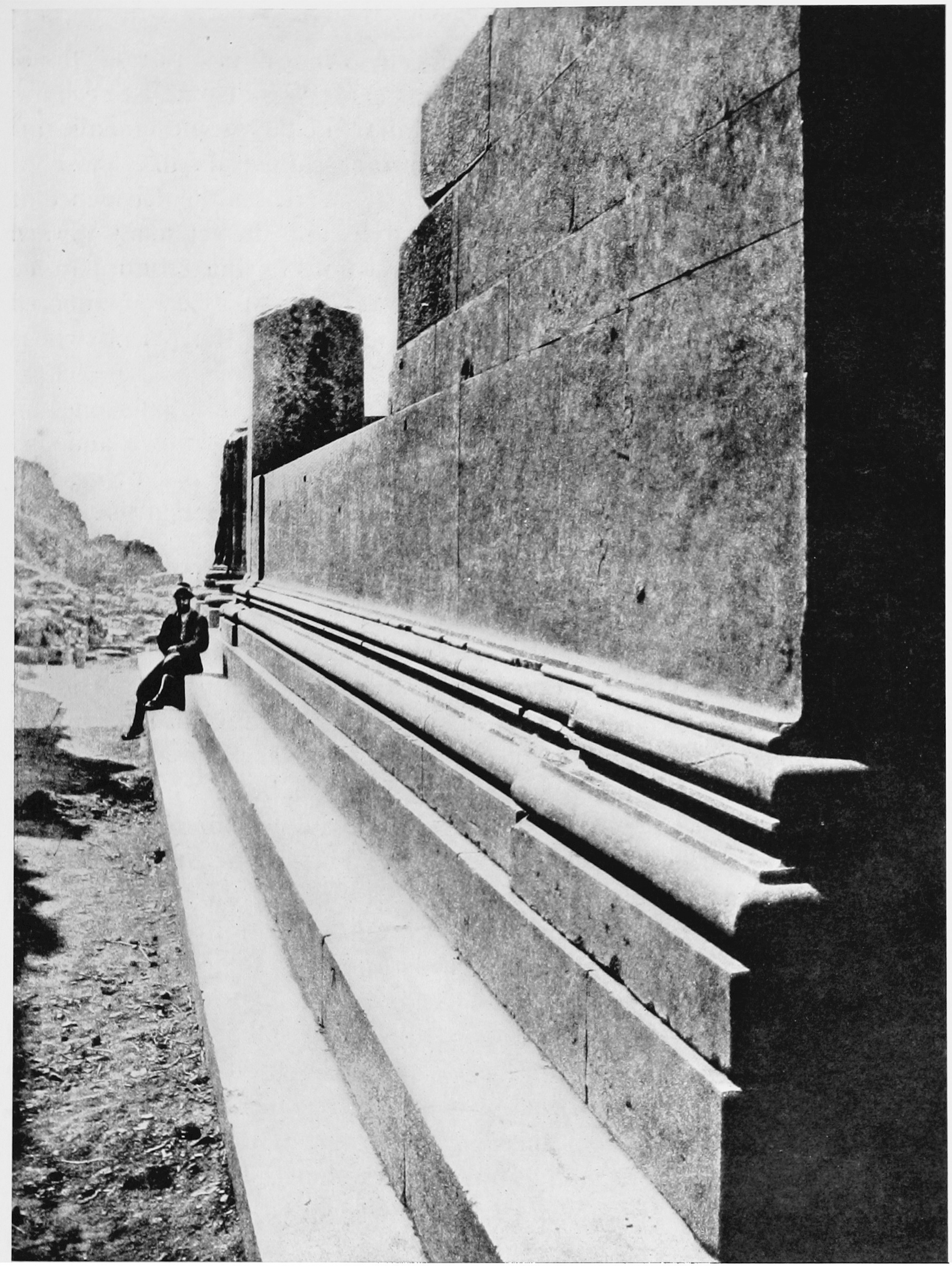


Fig. 72. Curves in Elevation of the Ionic Temple at Pergamus, West Flank.
From "Die Altertümer von Pergamon."

The rising convexity has been measured by Dr. Richard Bohn as 5½ cm. in a length of 21.60 metres. The curve as found in the steps and water-table is said to be diminished, or to disappear, in the masonry of the wall.

Colonial examples there is no entasis at all." On this head an examination of the careful records which have been made by Koldewey and Puchstein shows that out of eighteen temple ruins in the Western Colonies, for which information on this subject may be obtained, there are nine instances of temples with entasis, one instance in which the unfinished condition of the temple is known to explain the absence of entasis, five instances which are uncertain, two instances in which it is probably not found, and only one instance in which it is positively not found. The individual temples, and the page references from which this summary is compiled, are mentioned in the Appendix[7]. It thus appears that the entasis must have been very frequent in the Greek Colonial temples.

## RECENT OBSERVATIONS

BESIDES the mention of the Greek temple ruins which are definitely known to have no curvature, some others may be cited as being cases for which no information is obtainable, or which, at least, have not hitherto achieved publicity in this direction. There are nine temples at Selinus in such a state of ruin, due to earthquakes, that no examination of the stylobates for curvature is possible. Out of eight temple ruins at Girgenti, there are only two which are in such preservation as to allow of examination in this particular. These are the so-called temples of Concord and of Juno Lacinia. Even for these two instances the only observations so far published for curvature appear to be those attested by the photographs which were made by the Brooklyn Institute Museum research of 1895 (Figs. 79, 81, 84, pp. 141, 145, 149).[8] These curvatures, which are confined to the flanks and not found on the fronts, have been overlooked, for instance, by the work of Koldewey and Puchstein.

As far as I am aware, the only record for curvature in the temple ruins of Asia Minor is that of the Ionic temple at Pergamus (Fig. 72, p. 123).[9] As regards the islands of the Ægean the only observation known to me is that of Robert Koldewey, who has observed constructive curvature in the platform of an important, but almost wholly ruined, Ionic temple of the early fourth century B.C., at Messa on the island of Lesbos.[10] The only published records for Roman curvatures are those for Cori and Nîmes, aside from those now made in the Appendix[11].

Besides these indications of our scanty and fragmentary knowledge of the subject, we have finally to lay stress on the wholly recent dates at which much of this imperfect knowledge has been obtained, as, for instance, the publication of the concave curvatures at Cori in 1904, at Pæstum in 1907, and at Egesta in 1909. Such recent additions to our knowledge suggest that other additions to it may still be made, even among the limited number of extant Roman ruins having the requisite preservation.[12]

A curious instance of the point that important facts of this description frequently escape or elude detection for many years is offered by the recent date of the observation (1899), by Koldewey and Puchstein (see Appendix[1]), for curves in elevation *on the flanks* of the stylobate of the temple of Poseidon at Pæstum, which they have measured (pp. 25, 26 of their work) as having a constructive rising convexity of about 4 cm. Penrose states that the curves in elevation of the Poseidon temple are confined to its fronts.

This erroneous supposition is his main argument for his theory that the Greek curves were at first constructed only under the gables, as is shown by the following quotation, where he says of the Greek curvature (p. 104): "The fact of its being found in the fronts only of the temple of Neptune at Pæstum, which is no doubt a very early example, is decisive of its being derived from the pediment; for otherwise it would have been equally or more important on the flanks." Burckhardt only mentions the convex curves in plan on the flanks. Now we become aware, as recently as 1899, that the flanks of this temple have both kinds of curves.[13]

Three observers, of whom I was one, overlooked these curves in elevation on the flanks, in 1895, although all the photographs of curvature from Pæstum which are published in this volume were made at that time. One of the photographs actually shows a curve in elevation (Fig. 73, p. 127) on the entablature of the north flank, but knowing that its convex curve in plan would produce this effect in a photograph, I had attributed the entire photographic effect to this other known cause.

On the other hand, our party observed and photographed curves in elevation, which were not noticed by Koldewey and Puchstein, in two temples at Girgenti. Their book makes a special note of the apparent absence of curvature in the temple of Juno Lacinia, although this curve is very plainly shown by Fig. 84, p. 149.[a] The explanation of all these oversights is that curvature is the universal and normal optical appearance of all perspective lines, and that the observer has the unconscious or subconscious

[a] "Die Säulenplinthen und die Intercolumnien des zweisteinigen *anscheinend nicht curvirten* Stylobats sind einander durchaus gleich." (Page 167.)

Fig. 73. Curves in Elevation, Entablature of the Temple of Poseidon at Pæstum, North Flank. Brooklyn Institute Museum Series of 1895.
A straight line has been ruled on the abaci to show the curvature. The corresponding curve of the stylobate has been measured by Koldewey and Puchstein as having a rising convexity of 4 cm.

habit of making mental correction (pp. 56, 57), so that the lines are habitually seen as straight. This mental correction naturally includes the constructive curvature, which is unconsciously reckoned in with the perspective effect.

We may conclude this chapter, which has been mainly devoted to the deficiencies of our knowledge and the gaps in the record on the given subject, with some additional and suggestive illustrations of these deficiencies.

In spite of the accessibility and importance of the so-called Basilica at Pæstum, we have no present knowledge of the upper diameter and related diminution of its columns, which is visibly very remarkable. We do not even know their true height. The measurements of Labrouste and Delagardette,[a] which are the only ones extant for this ruin above the surface level, vary by 37 cm., or 14½ inches.[b] On this head the remarks of Koldewey and Puchstein, who quote these discrepant measures, are as follows: "It is really remarkable in the highest degree, in the case of a building which is so easily accessible, which has been so often examined, and which is so well guarded, that we are not able to indicate with any certainty even the measures for the columnar height or the upper diameter."[c]

Another point relates to the forward inclination of the front vertical faces of the Doric abaci, which is found in the Parthenon[d] and in the Propylæa,[e] and which was not otherwise known to Penrose. His explanation of this peculiarity, as of the same arrangement in the vertical face of the cornice (the corona), is attractive and convincing, viz., that it "may have been intended to increase the contrast in the effect of light on the abacus, as compared with that on the faces of the entablature, which incline in a contrary direction."

Up to the present date and in the whole range of Greek temple ruins, which have rarely been examined from scaffolds outside of Athens, there are only two known additional instances of the forward inclination of the front faces of the Doric abaci. These were observed and measured by Director Giuseppe Patricolo, the government official in charge of the Sicilian ruins, as being found in the temple at Egesta and in the so-called temple of Concord at Girgenti.[f]

[a] See Appendix 14.

[b] Labrouste, m. 6.48; Delagardette, m. 6.11.

[c] K. and P., p. 18. The latter measurement is, of course, essential to a knowledge of the amount of diminution in the shafts. See Fig. 77, p. 135.

[d] Penrose, p. 15.

[e] Penrose, p. 71. He mentions there that "this peculiarity is not found in other Athenian examples."

[f] The distinguished author, who has done so much for the preservation and the knowledge of

Thus in the whole range of known Doric ruins there are only four records for this treatment of the abacus, which must have been quite frequent, if we may argue this frequency from the absence of intimate relations between the Athenians and the given Sicilian Colonies, and the distance which separated them.

As regards the inclination of the antæ there do not appear to be any records outside of those of Penrose for the Athenian monuments. In the matter of columnar inclinations, Koldewey and Puchstein have furnished some data both of their presence and absence. They are found, for instance, in the temple of Poseidon at Pæstum.[a] They are not found in the temple of Concord at Girgenti.[b]

The general lack of information on these and other related subjects is due partly to the expense of scaffolds and of the surveying expeditions which might use them, and partly to the great dilapidation of most of the extant monuments. It must be remembered that the only Greek temples in even approximately good preservation, outside of Athens, are one at Egesta, one at Girgenti, and one at Pæstum. This simple statement is the most potent conclusion which can be offered to the general argument of this chapter.[14]

the Sicilian ruins, was kind enough to present me with his monograph on this subject at Palermo, in 1895; but, having mislaid this copy, I am obliged to refer to the quotation of these facts as made by Koldewey and Puchstein at p. 173 of the work mentioned in Appendix[1] of this chapter.

[a] K. and P., p. 26. The drums vary in height on opposite sides 1–2 cm., and certainly 2 cm. at the angles. [b] K. and P., p. 173.

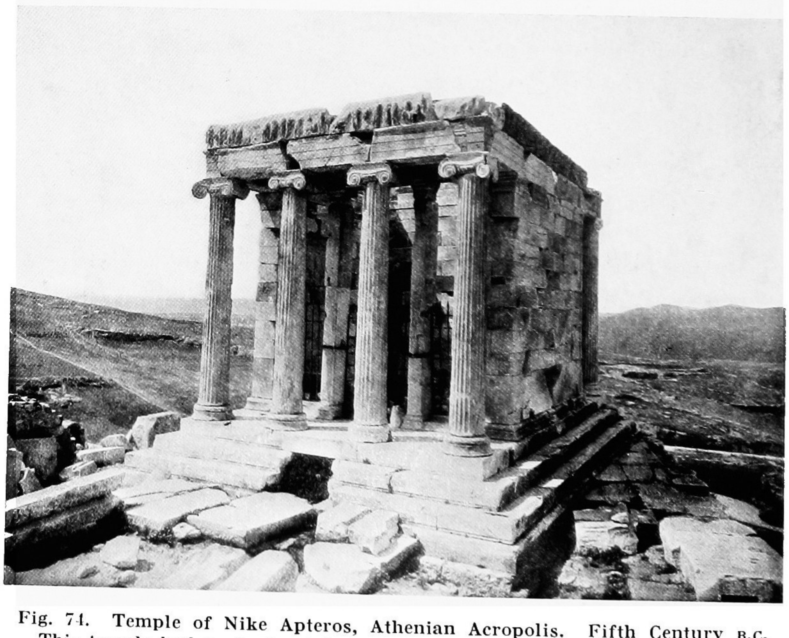


Fig. 74. Temple of Nike Apteros, Athenian Acropolis. Fifth Century B.C. This temple had no horizontal curvature, according to Penrose. It was rebuilt in 1835–6, with the original masonry, which had been used for a fortification by the Turks.

# APPENDIX. CHAPTER IV

[1] The recent elaborate folio publication by Koldewey and Puchstein on the temples of lower Italy and Sicily (*Die Griechischen Tempel in Unteritalien und Sicilien;* Berlin, Asher, 1899, Behrend & Co., Successors) will be referred to in the next chapter. This valuable work does not include any observations which would have required the construction of scaffolding, a deficiency, due to financial limitations, which is noted with regret by the authors and for which they are not responsible. This deficiency is to be especially regretted in the case of the Poseidon temple at Pæstum, of the temple at Egesta, and of the so-called temples of Concord and Juno Lacinia at Girgenti.

All later references to Koldewey and Puchstein, or to K. and P., indicate this work.

[2] The primary subject of this essay (pp. 145–154, Plates XIII, XIII *bis*) was an "Explanation of the Curves in Greek Doric Buildings." Its theory was a modification or expansion of that of Penrose, and considered the curvature of the sky as operating, like a gable, to deflect the horizontal lines of the Greek temples downward toward the centre. A discussion of this theory has appeared unnecessary, in view of its great improbability. Burnouf was director of the French School at Athens, 1867–75. He was born in 1821.

[3] The point is not mentioned in the *Histoire de l'Architecture,* and Choisy's *Vitruve* (1909) adopts the inadequate explanation of Aurès (Vol. I, p. 146; Plate XXXIV, Vol. II).

[4] The first later mention of this explanation of the *scamilli impares* appeared in my articles which are quoted at p. 47, foot-note[b].

[5] It is stated in this essay that the columns of the Parthenon are arranged in convex curves in plan. Of this arrangement Burnouf says: "Elle est faible, mais elle existe." No other modern authority has published this fact, and no one has contested it. Burnouf's official position as director of the French School at Athens for a period of eight years gives his observation a certain weight, and, if correct, it is extremely important, as duplicating the similar arrangement on the flanks of the Poseidon temple at Pæstum. The statement must, however, be considered as limited to the flanks of the Parthenon, because the concave curve in plan on the fronts begins with the capitals.

[6] Professor W. Dörpfeld, in *Olympia* (Berlin, Asher, 1892; Behrend & Co., Successors). Dörpfeld has found irregular curves in elevation in the temple of Zeus, which he attributes to subsidence, but it may be that this subsidence has only distorted the

originally more regular curves. There are very remarkable curves in plan convex to exterior in the walls of the Bouleuterion at Olympia. They offer striking analogies with the mediæval curvatures in plan, and again suggest the poverty of our real knowledge of classic architecture. See *Die Ausgrabungen zu Olympia,* Berlin, Asher, 1880; Behrend & Co., Successors (a distinct work from the one above quoted). Dörpfeld says (Vol. IV, pp. 40–46): "It is a very remarkable fact that the breadth of the main hall, which is m. 11.02 at the entrance end on the east, increases to m. 11.07 at the centre, and again diminishes to m. 10.42 at the west wall. Thus there is a transition, with continuous curving line, to the curve of the apse, which is not a half circle, but a half ellipse."

[7] The following references for the entasis in the Western Greek Colonies are quoted from the work mentioned in Appendix[1] of this chapter:

Fig. 75. Temple of Castor and Pollux, Girgenti. This angle of the temple is a modern reconstruction from ancient fragments.

Recorded as having the entasis are: the Tavole Paladine, about 510 B.C. (fifteen columns standing), about three miles distant from Metaponto (p. 36); the so-called Basilica at Pæstum, now known to have been a Doric temple of the sixth century, about 570–554 B.C. (p. 13); the so-called temple of Ceres at Pæstum, about 540 B.C. (p. 19); the so-called temple of Poseidon at Pæstum, about 440 B.C. (p. 26); the temple of Athena on the island of Ortygia at Syracuse, early Doric (p. 69); the Asklepieion, outside the walls at Girgenti, earlier than 210 B.C. (p. 184); the so-called temple of Concord, Girgenti, 430–420 B.C. (p. 173); the so-called temple of Hercules at Girgenti, about 500 B.C. (p. 148); Temple D at Selinus, about 570–554 B.C. (p. 108).

The columns at Egesta (430–420 B.C.) were unfinished, as regards the flutings, and hence the entasis does not appear, but its use was intended, as shown by the strongly accented diminution: "Daher lässt sich die beabsichtigte Schwellung nicht erkennen und nur die Verjüngung vernehmen" (p. 134).

The following instances are uncertain: the temple of Apollo on the island of Ortygia at Syracuse, about 581 B.C. (p. 63); Temple F at Selinus, about 570–544 B.C. (p. 119); Temple E at Selinus, early fifth-century Doric (p. 130); the so-called temple of Castor and Pollux at Girgenti, after 338 B.C. (p. 178); and the so-called temple of Juno Lacinia at Girgenti, early fifth-century Doric (p. 169).

Temple C at Selinus, about 581 B.C., probably had no entasis (p. 99). The sanctuary of Hera on the Italian coast south of Crotona, about seven miles from the modern town of Cotrone, fifth-century Doric, also probably had no entasis (p. 42).

The temple of Zeus at Syracuse, about 581 B.C., has no entasis (p. 67).

Fig. 76. Curve in Elevation, Front Cornice of the Pantheon.

A straight line has been ruled under the egg-and-dart moulding of the cornice, and just above this straight line the curve is easily visible, when sighted sideways. Brooklyn Institute Museum Series of 1895.

[8] These were first published in the articles quoted in foot-note[b], p. 47. The only published photographs for the curvatures at Egesta and at Pæstum are those made by the same research. One of the former, as photographed by the Brooklyn Institute Survey, was published by Sturgis in his *History of Architecture,* Vol. I, p. 154. Mr. L. Earle Rowe, Director of the Rhode Island School of Design, has, however, recently presented me with an excellent photograph of the curvature in the temple of Concord, which he personally made of that building (Fig. 63, p. 39). As regards the absence of curvature in the fronts of the temple of Concord, see p. 64 and Fig. 41, p. 65. The same peculiarity holds of the temple of Juno Lacinia.

[9] Published in Vol. IV, Plate XXXI, of the *Altertümer von Pergamon* (Berlin, Spemann, 1896). The text, by Richard Bohn, mentions only rising curves in elevation, but the photograph (Fig. 72, p. 123) also appears to show a delicate curve in plan convex to exterior. There is no curvature on the south front. On the north front and east flank the condition of the ruin does not allow of determination on this point. Dr. Bohn thus confines his observation for the west flank to the statement that its curve is certainly not due to settlement of the masonry.

Fig. 77. The Entasis at Pæstum. The so-called Basilica, a Sixth-century Temple.

[10] "Die Stylobatoberkante war nicht eine gerade Linie, sondern curvirt." The facts showing constructive intention are quoted. See p. 54, *Die antiken Baureste der Insel Lesbos im Auftrage des Kaiserlich Deutschen Archæologischen Instituts. Untersuchung aufgenommen von Robert Koldewey.* Berlin, Reimer, 1890. Durm, as usual, is not convinced. See p. 134, *Baukunst der Griechen,* 3d edition.

[11] The rear of the temple of Fortuna Virilis (so called) at Rome (late Republic) has a curve in plan convex to exterior in the cornice. The front curve has been destroyed by repair, and an American architect, Mr. Wm. Welles Bosworth of New York, has verbally mentioned to me the contrast between the two ends of the temple as being much to the disadvantage of the front.

There is also a rising curve in elevation in the front cornice of the Pantheon, which was photographed in 1895 by the Brooklyn Museum research and which has never previously been published (Fig. 76). This curvature may be accidental, but its existence is worthy of mention. It appears to be confined to the cornice. Repairs at the angle (in the foreground of Fig. 76) have distorted the lines of the fillet and entablature. The photograph was taken from the most southerly upper window of the Albergo del Senato, which sights directly on the level of the curve, and it is only from this point that it can either be photographed or seen. It is, of course, universally true that no curves in elevation in the upper lines of any temple can be observed by the eye, otherwise than from scaffolds, or from another adjacent building of equal height, which allows of sighting on the given line *from a position in which it is almost wholly foreshortened.* Curves in elevation in the entablature of a temple can never be seen from the earth's surface. They are discounted by the eye as a perspective effect.

[12] The stylobate of the temple of Minerva, at Assisi, has a curve in elevation in the front platform, but this is due to accident, being caused by the weight of a mediæval bell-tower near one of the angles. Sighting from an adjacent building on the level of the entablature showed it to have no curvature in elevation.

Observations as to curvature for the temples at Vienne and at Pola, which are unknown to me, are much to be desired.

[13] There is no known Greek instance in which the stylobate curves are not also found in the entablature; and although, for want of scaffolding, the observation of Koldewey and Puchstein is confined to the stylobate, it may be safely assumed that this curve in elevation is also found in the upper horizontal lines. The Brooklyn Institute photograph of the north flank (Fig. 73, p. 127) shows such a curve in the entablature, but this is not conclusive evidence, when considered apart from the recent authentic observation, because the convex curve in plan (Fig. 26, p. 39) would of itself produce such an optical appearance in the photograph.

[14] The relative deficiencies of our information about these temples, when compared with the observations of Penrose at Athens, may be argued from the following facts regarding the publications which relate to them. The most recent, as well as the most thorough and reliable observations, which are those of Koldewey and Puchstein, were necessarily made without the assistance of scaffolds, as explained in Appendix[1] of this chapter. The publications of Delagardette, *Les Ruines de Pæstum* (1799), and of Labrouste, *Les Temples de Pæstum* (1829), were made, according to the mentioned dates, before the discoveries of the Greek refinements, and therefore contain no information about them. The elaborate publication of A. Aurès, *Étude des dimensions du grand Temple de Pæstum* (1868), is avowedly devoted solely to the effort to prove that the standard of measurement in the so-called temple of Poseidon was the Italic foot. This effort is mentioned by K. and P. (p. 31) as wholly unsuccessful ("vollständig misslungen"), in view of the main dimensions of the ground-plan. Aurès did not make any original measurements of this temple. He preferred to rely entirely on those of his above-named predecessors. He states as his reason for this that his own measures might be open to attack, as being those of a prejudiced party.

As regards the Sicilian temples, both of the monumental publications which preceded the work of K. and P. are of earlier date than the discovery of the Greek refinements. The work of the Duca di Serradifalco, *Antichità di Sicilia,* dates from 1834, and the work of Hittorff and Zanth, *Architecture Antique de la Sicile,* bears the date 1827, as regards plates and measurements, although a second edition, with text, dates from 1870.

# CHAPTER FIVE

## EXPLANATIONS OF THE GREEK HORIZONTAL CURVATURE AS DESIGNED FOR PERSPECTIVE ILLUSION

## VERTICAL INCLINATIONS IN THE GREEK TEMPLES

Fig. 78. The Temple of Poseidon at Pæstum. West Front and South Side.
Brooklyn Institute Museum Series of 1895.

# CHAPTER V

## EXPLANATIONS OF THE GREEK HORIZONTAL CURVATURE AS DESIGNED FOR PERSPECTIVE ILLUSION

Among the various explanations which have been offered for the Greek curvature, the suggestion of Hoffer that it was designed to produce a perspective illusion has already been referred to, but without discussion (p. 57). The subject cannot, however, be abandoned without noticing this theory.

This perspective theory of Hoffer was revived by Hauck, with modifications which have been briefly described.[a] It is worthy of mention, in view of Hauck's high authority as an optical expert, that his objections to Hoffer's theory were sentimental and not optical. As a devotee of Greek art he refused to believe that the Greeks could have been guilty of an optical trick, but as an expert in optics he found no fault with the theory as related to optical laws and effects. In fact, Hauck's own theory was a tribute to that of Hoffer and a repetition of it as regards the essential point of the effect of the curvature.

Hauck supposed that the Greeks were compelled to resort to perspective illusion by means of the curvature, because the problem of the angle triglyph,[b] in the use of the Doric Order, involved a spacial contraction of the intercolumniations at the angles and a related contraction of the metope widths in the same direction (in the Parthenon metopes). This latter contraction was explained by Hauck as an "echo" of the columnar contraction. These arrangements, as seen when facing any side of the temple and nearly opposite its centre, must have produced, in Hauck's opinion, an exaggeration of perspective which was not intended, but which demanded, according to his views, a corresponding exaggeration of perspective effect in the upper horizontal lines, by means of the curves in elevation. Otherwise, his theory holds; there must have been a contradiction of optical effects.

[a] See Appendix[5], Chapter II, p. 76. [b] See pp. 20, 184, 192.

It appears unlikely that the Greeks would have been disturbed by such an optical contradiction. Indeed, such contradictions or confusions of effect appear to be contributory to optical interest in mediæval work, as already perceived by Mr. Ruskin.[1] At all events, other and various objections which vitiate the theory of Hauck have already been mentioned (pp. 63, 79). It must, however, be remembered that Hauck was simply offering *a new version of Hoffer's theory,* rather than a new theory, and that as far as the optical facts and optical theories of curves are concerned *both authorities agree.* It must therefore be conceded, on the strength of the best optical authority, that the Greek curvatures in elevation tend to accent and increase a normal perspective effect.[a]

Émile Boutmy has also conceived that a perspective illusion was purposed, not only by the curvature in elevation but also by the inward inclination of the columns and by the narrowing of the metope widths (in the Parthenon).[2]

Finally, Thiersch, who was not disposed to consider the strong diminution of the Doric shaft as intended for perspective illusion, still points out that it has this result as a matter of fact.[3]

It may be added that the convex curvature in plan, as found at Nîmes, at Pæstum, and in Egypt, is undoubtedly contributory to an effect of exaggerated perspective. The convex curvature in plan (above the eye) resembles the curvature in elevation as regards the nature of the optical effect, but it differs from it by an enormous exaggeration of this effect on near approach.[b] At the angle of 45° a curve in plan with a convex projection of five inches will appear equal to a curve in elevation of the same amount, and it will appear to be less than such a curve at a greater distance; but on closer approach the optical exaggeration increases rapidly, and it is, moreover, quite impossible for the eye to detect the illusion, because the normal perspective curvature is itself so much greater on near approach, when the spectator is obliged to look upward and turn the eyes and the head in order to take in the whole of the given horizontal line.

The existence of such a powerful perspective illusion in the convex curves in plan (whose existence was unknown to Hoffer) may tend to increase our interest in his theory, and especially because his point of view was not confined to this theory and because his appreciation of the æsthetic advantage of the curvature was so enthusiastic (p. 83). We must, how-

[a] The concave curvature in plan was, however, incomprehensible to Hoffer, as he expressly states, and its optical effect is contradictory to the normal perspective effect, especially on close approach. The best explanation of this curvature is that of Michaelis (p. 91).

[b] See Appendix[4], Chapter II, p. 75.

Fig. 79. Curves in Elevation of the Stylobate, South Flank, Temple of Concord at Girgenti.
Brooklyn Institute Museum Series of 1895.

ever, consider the temperamental explanation as the dominant and important one. The main reason for holding fast to the point of view which has found favor with so many experts (not excepting Hoffer), and with so many art historians,[a] is derived from that approach to the problem which endeavors to imagine what the architect who wished to improve the effect of a Greek temple would reasonably and naturally have done in that case.

In view of that extremely cold and dry effect of the modern Greek temple copies which has been expressly mentioned by Penrose, and which is otherwise widely recognised, it appears probable that the rigid straight lines of the early originals must also have involved a similar defect. It could never have occurred to an artist to remedy such a defect by making the temple look larger. He would rather have striven to soften its lines, to give them a graceful and supple elasticity, and to introduce the element of life and variety by the various devices which have recently become familiar to us. That several of these devices increase the effect of dimension may be readily admitted, but it appears unlikely that this would have been the first purpose and the leading idea of the designer.

It must still be conceded that the best-preserved Greek temples have an effect of overpowering grandeur which could hardly be expected from their actual dimensions. This is especially true of the so-called temple of Poseidon at Pæstum, which is only 197 feet by 80 feet in plan. In this temple the diminution of the shafts is very pronounced, being 21 inches, on a lower diameter of 78 inches, in a height of 26 feet 6 inches (upper diameter, 57 inches). The inward inclination of the shafts is also established.[b] All of these features would optically exaggerate dimension.[c]

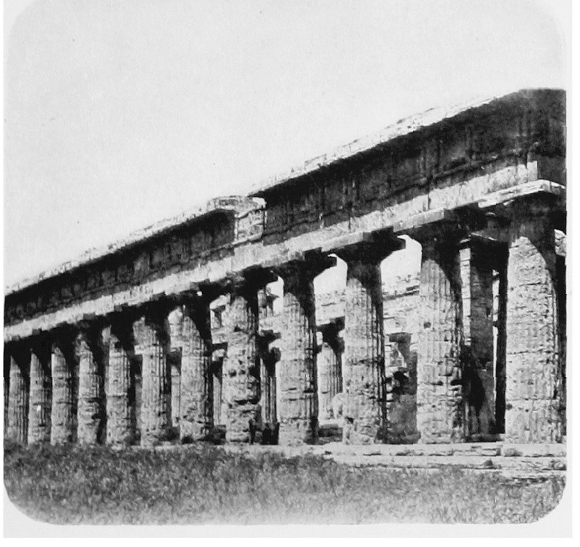


Fig. 80. Temple of Poseidon, Pæstum. South Flank.

The convex curvatures in plan of the cornices on the flanks undoubtedly also produce a strong perspective illusion, whatever their original and main purpose may have been. To both Winckelmann and Goethe, the acquaintance with this temple was an epoch-making event and a turning-point in their conceptions of Greek art.[4] If it should appear

[a] See Chapter III.

[b] See p. 130.

[c] See Appendix[3] of this chapter.

that perspective illusion, as well as massive simplicity, has contributed to this triumph of art, the belated discovery of the fact will hardly diminish our admiration for the result.

This part of our subject may be concluded with the remark that there is ancient literary authority for the fact that the Greek architects were familiar with the effects of optical illusions and with the methods of producing them. The original Greek passage, which is found in the work of Heliodorus of Larissa, is placed on the title-page of Mr. Penrose's book, and in English translation runs as follows:

> The aim of the architect is to make his work harmonise with the demands of the senses and to devise methods for deceiving the eye, as far as possible; his object being [to achieve] not actual, but apparent, symmetry and eurythmy.[5]

## VERTICAL INCLINATIONS IN THE GREEK TEMPLES

THE references of this chapter to the undeniable perspective exaggeration resulting from the strong diminution of the Doric shaft and from the inward inclinations which are found in the colonnades of many Greek temples, offer a convenient occasion for an elaboration of the summary mention of the leaning columns which was made in the first chapter.

The inward inclination of the main vertical lines and surfaces is there mentioned (p. 19) as giving "an effect of solidity and strength." This explanation coincides with that of Penrose, who says (p. 106), after speaking of the leaning columns:

> The remaining inclinations in the same direction—viz., those of the faces of the entablature, stylobate, and the side walls—are necessary in order that these parts may correspond with the axes of the columns and have at the same time the effect of giving generally to the entire structure *the pyramidal appearance so essential to the idea of repose and strength,* whilst they do not differ sufficiently from the perpendicular to impair the impression of energy.

There is, however, a secondary and not unimportant explanation of the columnar inclinations which sometimes, in recent works, figures as the only one. This explanation is the one which Penrose mentions first, and as the purely practical explanation is best suited to the comprehension of the average modern mind; it appears to have attracted the most attention.

On account of the pronounced diminution in the diameter of the Doric shaft,[a] the spaces between the columns just below the architrave are much

[a] In the Athenian Doric monuments the ratio of lower and upper diameters is mentioned by Penrose as 5:4. The diminution in the Parthenon is 7¼ inches (0.685 foot) in a height of about 32 feet.

Fig. 81. Curves in Elevation, North Flank of the Temple of Concord at Girgenti. Brooklyn Institute Museum Series of 1895.

Straight lines have been ruled on the steps and on the abaci to show the curvatures.

wider than they are on the platform. This effect of greater width at the tops of the columns is "cumulative towards the angles" (to quote the words of Penrose, p. 106), and the angle columns would therefore appear to lean outward, giving the effect of a fan-shaped arrangement, if it were not for the inward inclinations.

Fig. 82. The Doric Columnar Diminution. Interior of the Temple of Poseidon at Pæstum.

This explanation presumes, of course, that the inward inclinations at the angles are diagonal, as existing for both sides of the angle, and that the remaining columns on all sides are brought into parallel inclination with the angle columns. It may be added that the same effect of outward inclination would result from the tendency of the eye to see acute angles as being wider than they really are.[a] These effects exist, to some extent, as between the diverging sides of adjacent Doric columns and by reason of the diminution of the shafts. In all the columns of a portico, excepting those at the angles, these effects would neutralise one another, as operating in opposing directions on both sides of each column. At the angles this effect operates in the outward direction, without counterbalance, and thus the resulting fan-shaped appearance again needs a correction.

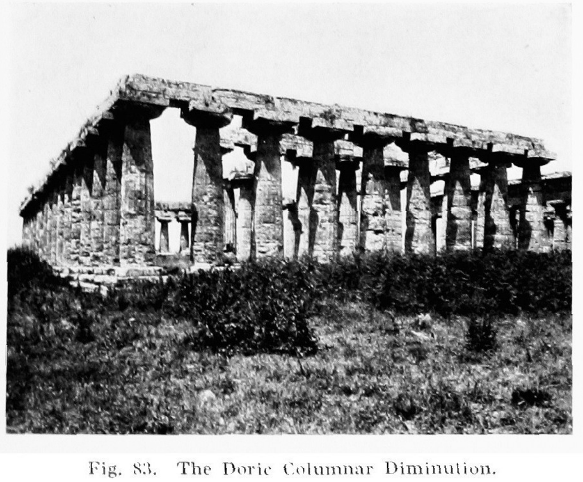


Fig. 83. The Doric Columnar Diminution. The so-called Basilica at Pæstum.

That the correction of these optical illusions is not the only purpose of the inward columnar inclination is apparent from the fact that the side walls of the Parthenon are also inclined inward, and to a greater extent than the columns, and that the inclinations in the axes of the columns are extended to the architrave and frieze on all sides of the temple.[b]

We shall not, however, forget

[a] See Chapter II, p. 60.

[b] See Appendix, Chapter I. These arrangements are also found in the Propylæa and Theseum.

that the vertical faces of the abaci, cornice, antefixes, and acroteria have forward inclinations, partly, it may be presumed, to evade the diminution of size which is due to foreshortening and partly to accent the effects and contrasts of light and shadow. It will be remembered that this forward inclination has also been established by Patricolo as holding for the faces of the abaci at Egesta and in the so-called temple of Concord at Girgenti (p. 129).

The forward inclination of the antæ is attributed by Penrose to the fact that those columns of the inner portico which face the antæ would otherwise appear to lean outward, on account of the strong diminution of the Doric shaft and the tendency of acute angles to appear wider than they really are.[a] Here Mr. Penrose appears to forget that the diminution of the outer columns of the portico would produce an opposing effect, and that these opposing illusions would paralyse one another, even if they operated to the extent imagined, which may be doubted. Hence the forward inclination of the antæ should be otherwise explained. Possibly the diminution of light under the ceiling of the portico may be the explanation. This diminishing light would tend to give an appearance of diminishing importance to the upper part of the pilaster, which would be counteracted by the greater emphasis resulting from a forward inclination. At all events, we may presume that an evasion of the foreshortening in perspective was considered desirable in the case of these angle pilasters.

A final point of great importance as to inclined verticals in Greek architecture is the direction of Vitruvius that the entire pediment shall have a forward inclination; he adds that it will otherwise appear to lean backward. This forward inclination is generally supposed not to occur in any known case in the surviving monuments, but Choisy says that the surface of the tympanum (or interior surface of the pediment) does lean forward in the Parthenon, and that the effect is "very happy," although it may be due to accident. No other authority mentions this fact, but it is undoubtedly authentic.[6]

Both Choisy and Penrose quote the direction of Vitruvius, without doubting that it represented an actual ancient practice. Vitruvius prescribed that the pediments and all surfaces above the columns should lean forward, one twelfth of the height of each member, but Penrose presumes (p. 38) that this is an error in the text, which used the Roman numerals, and that one fortieth of the height was the ratio meant. (The mistaken transcription of the MS. copyist would then have been from XL$^{ma}$ to XII$^{ma}$.)

[a] *Principles of Athenian Architecture*, p. 106. The antæ are the flat pilasters which face the ends of the side walls on the fronts of a temple. See Fig. 18, p. 30.

Fig. 84. Curves in Elevation, North Flank of the Temple of Juno Lacinia at Girgenti. Brooklyn Institute Museum Series of 1895.

Straight lines have been ruled under the steps and on the abaci in order to show the curvature.

We have now reached a point where the question may properly be raised: How did the introduction of all these various Greek devices actually come about, as a matter of fact? Common sense would lead us to suppose that, aside from Egyptian influence or example in the matter of the curves, and perhaps also in other directions, the introduction of the Greek refinements was gradual, tentative, and experimental, and that it was also temperamental, and controlled by the susceptibilities and sensitiveness of the individual architect. Only this point of view could explain the variations in the measurements for the same refinement in different buildings.

For instance, the measurements for horizontal curvature differ, as regards the relation of deflection to length, very considerably in different temples. The antæ of the Parthenon lean outward twice as much as they do in the Propylæa, and they do not incline at all in the Theseum.[a] The curvature of the temple of Corinth is confined to the front.[b] There is no recorded observation for a convex curvature in plan of the side cornices or columnar alignment for any extant Greek temple ruin, aside from the instance at Pæstum, unless the observation of Burnouf for the Parthenon should be authentic.[c] The columns are inclined in the temples of Rhamnus and Ægina and in the Erechtheum, although these temples have no curves.[d] The temple of Concord at Girgenti has no curves on the fronts, but has them on the flanks.[7] The entasis of the Erechtheum differs from all others in Greek art as regards its delicacy. The columns of the temple of Nike Apteros (so called) on the Athenian Acropolis, and of the best period of Greek art, have no entasis whatever. There also appears to be no entasis at Phigaleia.[e] It is supposed to have been a general rule in the Greek temples that the angle columns should be larger than the others (p. 9), but this does not occur in the Doric ruin near Metaponto known as the Tavole Paladine, neither is it the case in the temple of Poseidon at Pæstum.[f]

Fig. 85. Temple of Juno Lacinia, Girgenti. Fifth Century B.C.

[a] Penrose, p. 106. [b] Penrose, p. 28. [c] See Appendix[5], Chapter IV.
[d] Penrose, pp. 26 and 37, foot-note, for the Erechtheum.
[e] Penrose, pp. 27, 107, and 28.
[f] K. and P., pp. 36 and 26.

As for the Doric contractions of columnar spacing at the angles, which are called for by the problem of the angle triglyph, they have a different method, as regards the arrangement and amount of variation, in almost every temple which can be named.[a] In the Parthenon the contraction is confined to the spaces next the angles. In the temple of Poseidon at Pæstum there is a one-space contraction on the fronts and a two-space contraction on the sides. In many Sicilian temples there is a two-space contraction on the fronts and sides. In one Sicilian temple (Temple G at Selinus) there is spacial contraction on one front and none on the other.[b]

The raking gable lines of the Theseum have an upward curve, but no similar curves have been found in the raking gable lines of the Parthenon.[c] The raking gable lines of the Parthenon have a concave bend in the vertical plane, opposed in direction to these curves of the Theseum.[8] As for the variations in design, even of the apparently simple Doric capital, they are as numerous as the temples which have been examined. Within the limits of an individual temple, the design of the capital is also found to vary, not only where distinct changes of type appear, as in Temple G at Selinus (p. 166), but also within the limits of a single type and in a single temple. This is a well-known fact in the Parthenon, for instance.

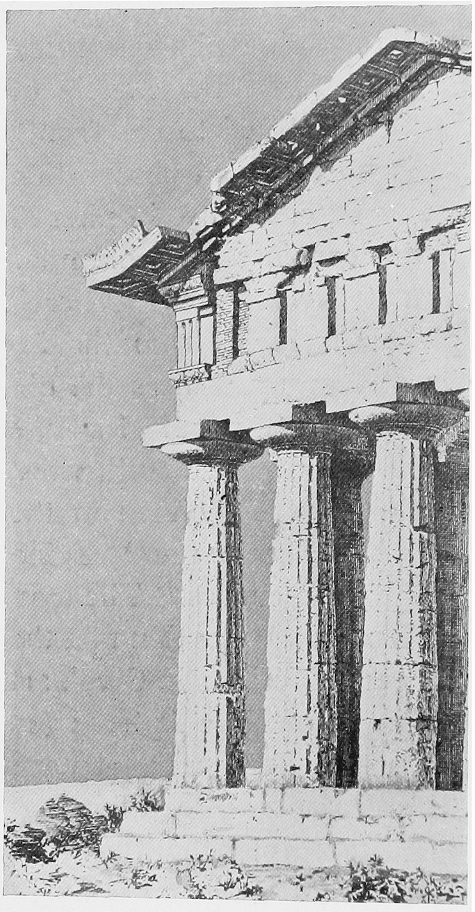


Fig. 86. Restoration of the Northwest Angle of the Temple of Ceres at Pæstum. From Koldewey and Puchstein.

Among the variations from canonical practice, which are not the less remarkable because they do not belong to the domain of refinements, is the discovery that the so-called temple of Ceres at Pæstum and Temple C at Selinus have their raking gable lines bent upward where they join the cornice of the entablature, in a manner somewhat resembling the eaves of a Chinese pagoda (Fig. 86, p. 152).[d] It is also worthy of mention

[a] For this problem see Chapter I, p. 20, and Chapter VI, pp. 184–186.

[b] For these variations as to spacial contraction see Koldewey and Puchstein, *Die Griechischen Tempel in Unteritalien und Sicilien*, pp. 198–200.

[c] Penrose, p. 73.

[d] K. and P., pp. 20, 21, 104, 105.

that, contrary to all supposed precedent, which allots only sixteen flutings to the early Doric shaft and only twenty flutings to the later Greek Doric shaft, there are two Doric temples with columns having twenty-four flutings.[9] These are the temple of Poseidon at Pæstum and the Doric ruin at Tarentum.[a]

All this is as it should be, and as we should expect it to be, when artists are in question and do what they please, as they please. It is not exactly "correct architecture," but that is never very good. There is nothing "correct" about real Greek architecture. The more we study this architecture, the more we find that the variations as between different temples, and the variations which are found in different parts of the same temple, really represent the same conditions and the same point of view. One class of variations involved the other. Thus the parallels with the infinite variety found in mediæval churches are much closer and much more numerous in

Fig. 87. The so-called Temple of Ceres at Pæstum. East Front. Dating about 540 B.C.

[a] K. and P., pp. 26 and 55, and mentioned as the only known instances of this peculiarity.

Greek architecture than they are generally presumed to be, in spite of the wholly different ideals and uses which separate these buildings in a spiritual, and also in an artistic, sense.

An additional and remarkable corroboration of this point of view will be offered in the next chapter.

Fig. 88. Hercules bearing off the Cercopes. Metope Sculpture in the Palermo Museum, from Temple C at Selinus. (See p. 175.)

# APPENDIX. CHAPTER V

[1] In Mr. Ruskin's description of the subtle asymmetric arcading of S. Giovanni Evangelista at Pistoja the following passage occurs: "The eye is thus thoroughly confused, and the building thrown into one mass, by the curious variations in the adjustments of the same shafts, etc." *Seven Lamps of Architecture*, The Lamp of Life, Section XIII. In Mr. Ruskin's description of the Venetian palace known as the Fondaco dei Turchi, its asymmetric arcading is described as "completely confusing the eye." An analogous philosophy appears to underlie the remark of Professor Adolf Michaelis (*Der Parthenon*, p. 18), that the incommensurable proportions and ratios of the Parthenon measurements probably contribute to its optical interest. This passage will be more fully quoted and discussed at p. 205 of this volume.

[2] *Le Parthénon et le Génie Grec*, p. 209. The first edition had a different title—*Philosophie de l'Architecture en Grèce.* Boutmy has also explained those variations in the dimensions of the abaci and capitals of the Parthenon east front, which are described at pp. 190–192 of Chapter VI, as calculated to produce an effect of increased perspective for points of view looking toward the angles of the east front. Although the main entrance was that on the east, the Parthenon was necessarily first seen, by every one ascending the Acropolis, on the west side, and from points looking toward the west front. This theory, therefore, appears improbable, and the true explanation is doubtless that of Hauck, as again mentioned at p. 192, Chapter VI, that it is an "echo" of the spacial contraction of the columns at the angles.

[3] "The diminution of the ancient columns is not, indeed, to be explained as designed for an appearance of greater height, but the value of that effect for an imposing appearance of the whole building is not to be underestimated." "Optische Täuschungen auf dem Gebiete der Architektur," in the *Zeitschrift für Bauwesen* for 1873, p. 15.

In view of the colossal effect and relatively small dimensions (197 by 80 feet) of the temple of Poseidon at Pæstum, where the diminution is more than one fourth of the diameter of the shafts, being 1¾ feet on a lower diameter of 6½ feet, and in a height of only 26½ feet, it seems desirable to quote at full length the explanation which Thiersch has given of the perspective illusion which is produced by the diminution of the Greek Doric shaft, and to reproduce the diagram which illustrates this explanation (Fig. 89):

"It is a fact that the upper diameter of columns which have a diminution always appears greater than it really is—*i.e.*, it appears to vary much less from the lower diameter than it really does. . . . It appears to me that the cause of this illusion is to be found in a certain perspective illusion which is peculiar to a column of conical form, especially when fluted, and which is due to the fact that this generally gives the impression of a more cylindrical and higher column which is foreshortened by perspective. Our eye is so accustomed to the appearance of parallel straight lines, which are met with almost everywhere, and has so learned by thousandfold experience to discount their apparent convergence, that it is disposed (at least partially) to attribute to perspective foreshortening the appearance of convergence in a number of lines which really converge towards one point. The act of vision, outside of the direct impression on the retina, consists only of the [mental] inference which is essential to perception, and which, through manifold experience and exercise since earliest childhood, takes place so mechanically and unconsciously that it escapes the control of conscious thought. Thus the most practised eye is exposed to the most overpowering deceptions. We need only consider the optical illusion in the case of the moon when it is near the horizon. Here it is the unconscious assumption of a greater distance, which is due to the number of intervening objects in front of the moon's disk, which causes it to appear larger than when it is high in the heavens. Measurement gives in both cases exactly the same diameter to the disk.

"If we look at a column with slight diminution and of large dimensions, as suggested by Fig. 89, the eye is misled to substitute in place of the conical shaft with the upper diameter *d*, a cylinder which is so much higher that its [lower] diameter *D* appears, at its upper end, to be not greater than *d*. The ratio between the supposed distance *E* and the actual distance *e* gives the following proportion—$e : E = d : D$. Such an illusion easily occurs in the case of large dimensions because, on account of the nature of the eye, the estimate of distances on a large scale is much more difficult than it is on a small one; and further, because the eye cannot measure, like a theodolite, the wider angles of altitude, and is also unable to embrace a large picture in clear definition, like a camera obscura. For, as only that small part of the retina which lies close to the axis of the eye can see a clearly defined picture, we are therefore obliged by up and down movement of the eye to change the pictures on this spot of the retina, and thus to piece together an impression of the whole from these various impressions. The apparent size—that is, the size of the picture on the retina—is mainly our standard for the estimate of distance, and this is exactly what produces the illusion in the given case. The more vertically we look upward, the more easily we are deceived, for the difference [in foreshortening] between the assumed height and the actual height is so much the smaller, and the judgment of the eye with the wider angle [of vision] is so much the less trustworthy. By actual test,

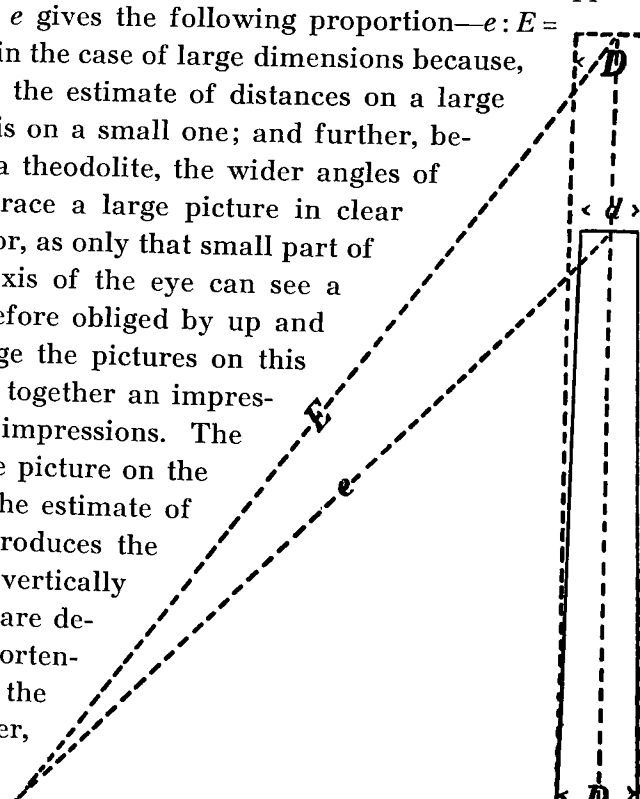



Fig. 89. Diagram to Illustrate the Illusion of Greater Height produced by the Diminution of the Doric Shaft. From Thiersch.

with large columns, a diminution in the ratio of 8 to 7 is not perceptible to the eye. The columns of the Glyptothek in Munich appear almost cylindrical, and yet the upper diameter is related to the lower as 6 to 7. If the columns were fluted, the diminution would be still less perceptible. For the multitude of lines converging toward one point strengthens the appearance of parallelism by the repetition of its apparent existence.

"Let us now suppose that we are looking at a Doric column belonging to one of the classic buildings in Athens. The diminution is so strong that the upper diameter relates to the lower as 4 to 5. It is clear that no one will here assume the form to be cylindrical. In spite of that, the impression of greater height also exists in the case of these strongly diminished columns when the eye is below the level of the bottom of the column. In the act of looking upward the eye anticipates, in any case, a marked convergence of the vertical lines, as a consequence of perspective foreshortening, and is unable to distinguish with certainty between the actual diminution and that which is due to perspective."

[4] See Bielschowsky, *Goethe, sein Leben und seine Werke* (Munich, 1904), Vol. I, p. 400; and Goethe's *Italienische Reise*, in the Diary dated Naples, March 23, 1787. Goethe's first impression at Pæstum was that of being in a wholly foreign world: "Ich befand mich in einer völlig fremden Welt."

Winckelmann repeatedly mentioned the Pæstum ruins, which he saw in 1758, as "the most astounding and attractive, . . . the most venerable [remains] of all Antiquity." See Carl Justi, *Winckelmann, sein Leben, seine Werke und seine Zeitgenossen,* Vol. II, p. 221.

[5] The sense of the passage is not wholly certain, but its reference to the subject of optical illusion is positive. Penrose offers no translation, but the tendency of his work shows that he construed the passage as bearing on the correction of optical illusion. Boutmy (p. 207 of his quoted work) translates the passage in the sense given in text, as bearing on the creation of optical illusion, and it is also the view of Hauck (p. 121 of his quoted work) that this is the correct meaning. The original Greek is as follows:

*Τέλος δέ ἀρχιτέκτονι τὸ πρὸς φαντασίαν εὔρυθμον ποιῆσαι τὸ ἔργον· και ὁπόσον ἐγχωρεῖ πρὸς τὰς τῆς ὄψεως ἀπάτας ἀλεξήματα ἀνευρίσκειν, οὐ τῆς κατ' ἀλήθειαν ἰσότητος ἢ εὐρυθμίας ἀλλὰ τῆς πρὸς τὴν ὄψιν στοχαζομένῳ.*

The date of Heliodorus of Larissa is unknown, but it was later than the time of Tiberius. The mentioned authorities who have quoted or referred to this passage appear to know it as an extract which is published in Schneider's *Vitruvius,* and give no further details. It is therefore worthy of mention that the original work is a *treatise on perspective* and was first published at Florence in 1573, with a Latin translation, and as an appendix to an Italian translation of Euclid's *Perspective.*

[6] *Histoire de l'Architecture,* Vol. I, p. 406:

"Inclinaison des frontons: Le fronton ne parait pas vertical.

"Vitruve connaissait cet effet: 'Si le fronton est vertical, nous dit-il, il paraîtra fuir en arrière.'

"Comme compensation, Vitruve conseille de donner à ce fronton du surplomb vers l'avant. Au Parthénon, les dalles du fronton présentent un surplomb dont l'effet est très heureux: mais leur inclinaison peut résulter de pures déformations et n'implique rien quant aux dispositions originelles."

[7] The absence of curvature in the entablature of the west front of the temple of Concord at Girgenti is established by a photograph which was made in parallel perspective by the Brooklyn Institute Museum Survey of 1895, and which is reproduced in Fig. 41, p. 65. It is probable that both fronts correspond in this particular.

[8] Hoffer, in the *Wiener Bauzeitung* for 1838, p. 388 and Plate CCXXXIX, Fig. 2. The sense of the passage below quoted from the original is that the pitch of the Parthenon raking gable lines is diminished in the blocks which support the acroteria at the angles, and that this diminution of the pitch is a reassurance for the eye as against a possible sliding outward of these blocks. This observation is quoted with approval by Michaelis, who adds (in foot-note 57, p. 19, of *Der Parthenon*) that when the sculptor Launitz was employed to prepare a gable group for the Hague Academy, in the early thirties, he independently, and before the date of Hoffer's observation, recommended the same procedure. Michaelis is not aware whether the suggestion was adopted by the architect.

(Launitz spent the later part of his life in the United States, and was a member of the Academy of Design. He died in New York in 1870. He was born in Courland in 1797, and was a pupil of Thorwaldsen.)

Hauck also refers to the given observation by Hoffer, in foot-note, p. 104, of his quoted work. The original passage in the *Wiener Bauzeitung* follows here:

"An den beiden Ecken, in Fig. 2, sieht man die Anordnung der Steine zur Aufnahme der Akroterien. Ich muss hierbei zugleich bemerken, dass die oberen Begrenzungslinien des Giebeldreieckes keineswegs gerade Linien sind, sondern dass beide sich in einer geschwungenen Linie nach oben hin ziehen, und zwar dergestalt, dass der Giebel anfänglich unter einem viel flacheren Winkel ansteigt und erst hinter der Akroterie seine richtige Neigung annimmt. Man glaubt es nicht, wenn man es nicht an Ort und Stelle gesehen hat, von wie beruhigender Wirkung diese Konstrukzion ist, da durch dieselbe der ängstliche Eindruck vollständig beseitigt wird, dass der Eckstein einmal nach aussen gedrängt werden könnte."

[9] Within recent years various instances of the occurrence of sixteen flutings have been observed in the Doric monuments of relatively late dates. The presumption that an early date is certainly determined by the use of sixteen flutings is no longer tenable, but it still appears, as a general rule, that there was a sequence in time, as between the temples with sixteen and those with twenty flutings. The larger number of flutings increases the effect of slenderness in the shaft by the additional emphasis which it gives to the vertical lines of shadow. Thus the change from sixteen to twenty flutings corresponded to a general tendency of the Doric order to abandon its early gravity and massiveness in favor of greater elegance and lighter proportions, without being an absolutely universal rule.

# CHAPTER SIX

# ASYMMETRIC DIMENSIONS IN GREEK TEMPLES

Fig. 90. Ruins of Temple C at Selinus. North Side. Early Sixth Century B.C.
Brooklyn Institute Museum Series of 1895.

# CHAPTER VI

## ASYMMETRIC DIMENSIONS IN GREEK TEMPLES

A MOST interesting illustration of the state of flux and of recent progress in the study of the irregularities of classic architecture is offered by the fact that the first complete series of thorough and systematic measurements for the Greek ruins of lower Italy and Sicily is as recent as 1899. In that year appeared the elaborate and exhaustive folio publication of Koldewey and Puchstein.[a]

From the standpoint of these authors formal regularity was the ultimate outcome and the desirable ideal of classic architecture. They are thus free from the imputation of special pleading, or of trying to make out a case for the existence of tolerated or purposed irregularities in the Greek temples. Their contribution to the subject is therefore all the more significant. Perhaps the full measure of this significance can be appreciated only by those who realise what remarkable analogies are to be found, in some of their surveys, with the purposely irregular intervals of Venetian or Pisan, or other Italo-Byzantine, arcading and columnar spacing, such as were first shown to exist by Mr. Ruskin,[b] and such as I have also repeatedly published in many examples.[c]

Fig. 91. Asymmetric Columns, Temple of Hera, Olympia. North Flank.

[a] *Die Griechischen Tempel in Unteritalien und Sicilien* (Berlin, Asher, 1899, Behrend & Co., Successors). For earlier publications on Sicily, see Appendix[24].

[b] *Seven Lamps of Architecture*, The Lamp of Life (1859). *Stones of Venice* (1851), Vol. II, Chapter V. The proofs of intention are found in the repetition of the same sequence of variations on two sides of one centre.

[c] See "Constructive Asymmetry in Mediæval Italian Churches," in the *Architectural Record*, Vol. VI, No. 3 (1897). The proofs of intention are found in the repetition of the same sequence

We must first distinguish, as regards this recent publication on the Greek temples, between the apparently or certainly heterogeneous asymmetries and those which its authors prove to be intentional. Before the date of Koldewey and Puchstein's work the only known and distinct analogy, in Greek architecture, to the heterogeneous dimensions and unsystematic irregular arrangements of the mediæval churches was the temple of Hera at Olympia. The heterogeneous features in this temple appear in the remarkable variations of columnar diameter, and in the varying designs of the Doric capitals.[1]

The explanation which has been offered for these irregularities is that the timber columns of an ancient temple founded in 1096 B.C. were gradually replaced by others of stone (beginning in the seventh century), at widely separated intervals of time, and of consequently different styles, as the decay of a particular column called for a special repair. But Professor Dörpfeld, who is the sponsor for this explanation, also adduces proof for the fact that there was a purposed and predetermined increase of 5½ inches in the average diameters of the columns of the fronts as compared with

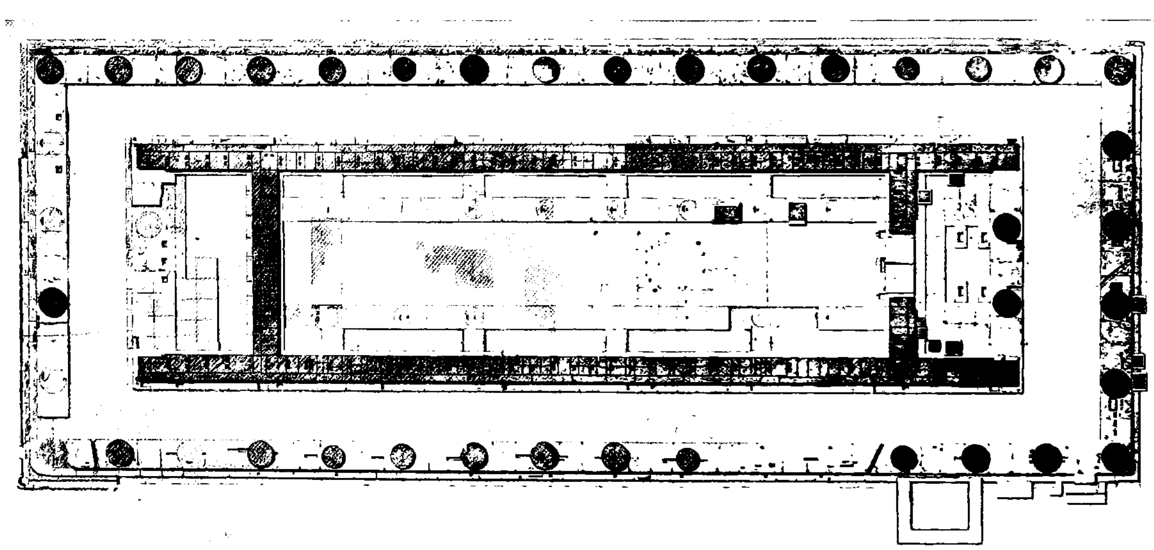
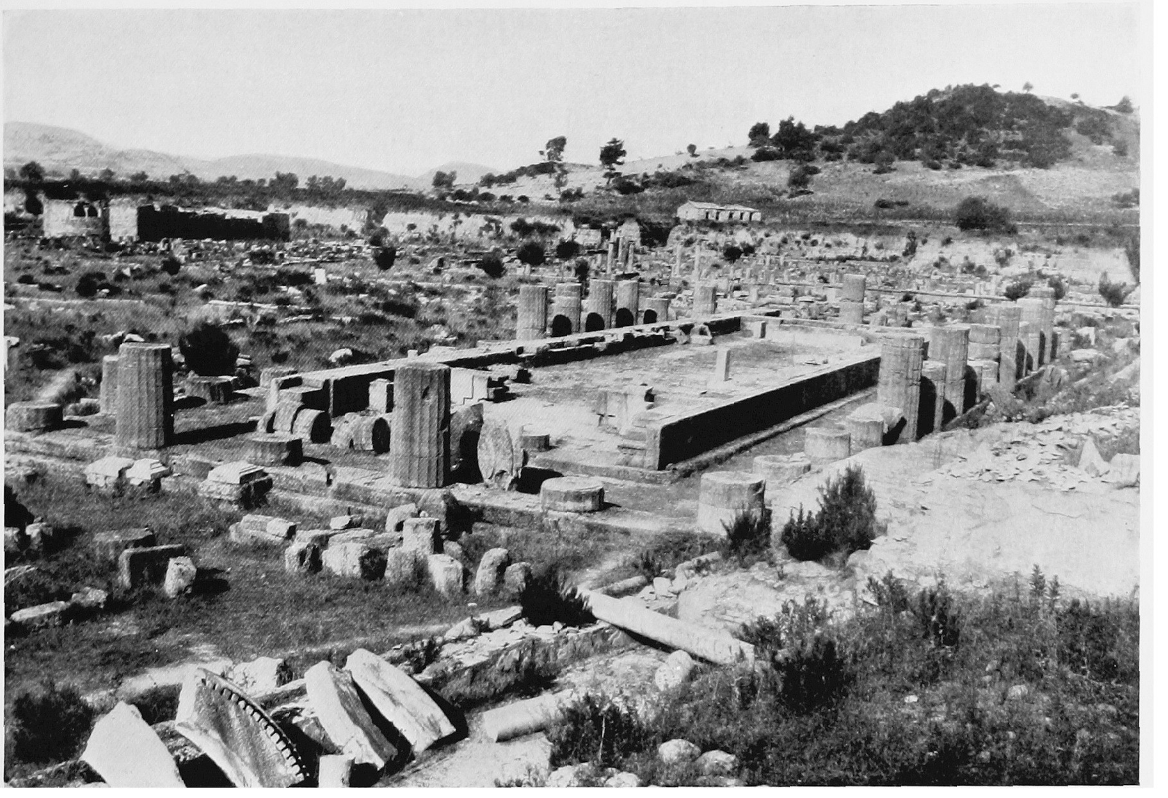


Fig. 92. Ground-plan, Temple of Hera, Olympia. From "Olympia: Die Baudenkmäler."
The columnar diameters average 5½ inches more on the fronts than on the sides. The axial spaces are 11½ inches wider on the fronts than on the sides.

those of the flanks,[2] and this predetermined and systematic asymmetry is also accompanied by a corresponding increase, in the average axial spacing on the fronts, of 11½ inches (29 cm.) for each intercolumniation.[3]

of variations on two sides of one centre, or on two sides of the same church. The existence of a single sequence of variations in measurement, if it occurs in regular progressive order in one extended series, is also a proof of intention.



Figs. 93, 94. Temple of Hera at Olympia. Asymmetric Columns of the North Flank.

Fig. 95. Ruins at Selinus. Temple E (foreground); Temple F (middle distance); Temple G (background).

As long as this Olympian temple was an isolated instance and one for which a special explanation was advanced as regards certain particulars, no general inferences could be drawn from it, and the matter-of-fact explanation offered for many of its irregularities also tended to minimise the apparent importance of those which were obviously purposed. But since the recent publication of Koldewey and Puchstein, it appears that some of the most remarkable instances, both of tolerated and of purposed irregularity, in the mediæval churches, have a multitude of parallels in the classic architecture of the Greeks—classic, indeed, not in the formalism sometimes supposed to be classic, but in the freedom and spontaneous individuality which no really classic art ever lacks, whether it be music, ornament, architecture, or literature.

The following details of this chapter relate mainly to ruins of which only the platform and the lower portions of the shafts, or very fragmentary remains of greater height, could be examined. With the principal exception of two ruins at Syracuse, these are the temples at Selinus, already

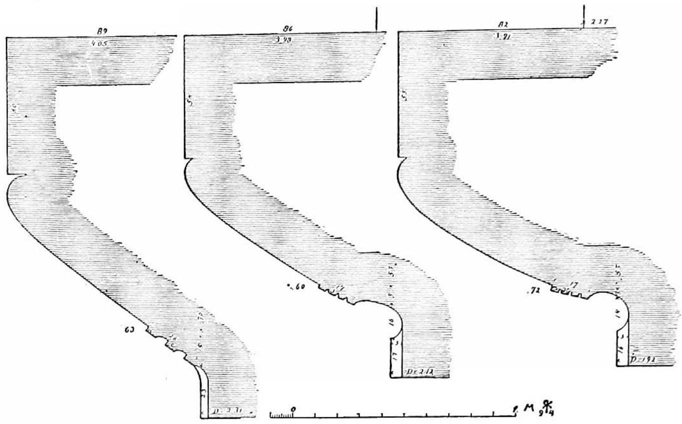


Fig. 96. Asymmetric Types of Doric Capitals from Temple G at Selinus. The earlier type is on the right; the later type is on the left; the intermediate type is in the centre. From Koldewey and Puchstein.

mentioned in the last chapter as having been so ruined by earthquakes that examinations for curvature, or for other refinements above the platform, are generally impossible. As regards these ruins, it may be added, for the benefit of those who have not seen them, that neither at Athens, Olympia, Pæstum, nor Girgenti is there any parallel to their number, or to their average dimensions, when considered as a collective whole. Although but one column is standing in the entire field of ruins, and that one in partial height, only the ruins of Thebes surpass them as surviving evidences of former architectural grandeur. Out of the six principal temples (there are altogether eleven temple and sanctuary ruins), Temple G was 87 feet longer than the Parthenon, and three other temples—E, C, and F—approached the length of the Parthenon within the limits of 5 feet, 23 feet, and 25 feet respectively.[4]

The temple of Apollo, usually known as Temple G, has three diverse types of Doric capitals. The plan according to which these capitals are found to be distributed indicates that two successive changes of type were made after the building was begun. To these variations in the capitals correspond different types of proportion in the shafts, whose upper diameters in the third type have a decrease of 0.39 m., or 15½ inches, as compared with the first type. The corresponding disparity in the lower drums amounts to 80–85 cm., or 32½–33½ inches.[5]

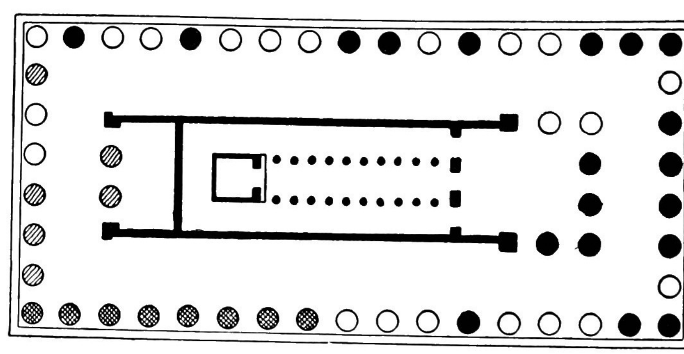


Fig. 97. Ground-plan of Temple G at Selinus, showing the Distribution of Capitals illustrated by Fig. 96. Black circles represent the earliest type of capital; circles with cross-lines represent the intermediate type; circles with parallel lines represent the later type; plain circles represent undetermined types. The distribution of the columns as regards discrepant diameters corresponds to the same circles. The larger diameters go with the early type of capital. From Koldewey and Puchstein.

It must be remembered, when these facts are mentioned, that this particular temple at Selinus has most exceptional dimensions, and that it ranks with the Zeus temple at Girgenti for its colossal size. The height of

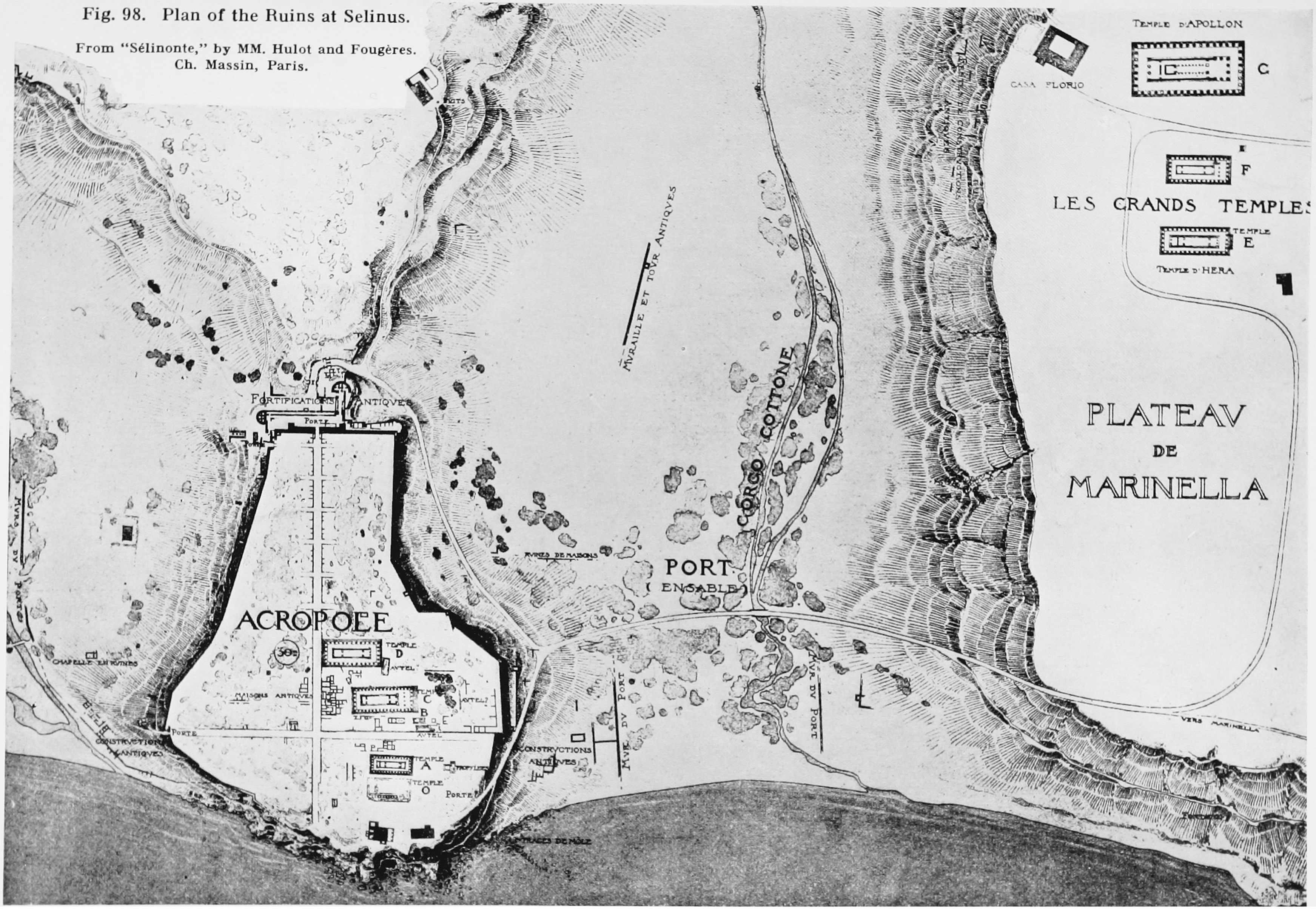



Fig. 98. Plan of the Ruins at Selinus.

From "Sélinonte," by MM. Hulot and Fougères. Ch. Massin, Paris.

the shafts is about 60 feet,[6] and the plan measures 50.10 m. by 110.36 m.[a] The excess of length over that of the Parthenon has already been mentioned as 87 feet, and the columns of the latter are about 26 feet less in height. The colossal dimensions of the shafts of Temple G are further indicated by the fact that the temple has only the same number of columns as the Parthenon (viz., 8 on the fronts and 17 on the flanks, angles counted both ways), although its dimensions are so much larger. Thus the actual discrepancies of dimension must be considered, as regards appearance, with reference to the great actual size of the temple. It may also be remembered that a difference of two feet in the angle-spacings of the Parthenon is practically imperceptible in the building, although more easily noticed in photographs, in which variations of dimension are often more apparent than they are in the actual building.

As regards the motive for the mentioned changes of type and proportion, the reader will also observe that the tendency of these successive changes in columnar diameter was toward a more slender column, and that this tendency corresponds to the one which is already well recognised in the history of Greek art—viz., to make the columnar proportions more and more slender in different temples of successively later dates. Here the same tendency is found in one temple which was begun in the sixth century and finished about the middle of the fifth.

Fig. 99. Ruins of Temple G at Selinus.

The optically inconspicuous character of these really great discrepancies will be better understood by the details in Appendix[5]. It will appear from these that either of the adjacent types of shaft did not vary in lower diameter by more than about sixteen inches. Although this variation might seem to be a large one, considerations below mentioned will tend to show that it was not especially noticeable.

Aside from what has just been said as to the relation of the dimensions

[a] As measured on plan, the temple of Zeus at Girgenti has the same length within a few centimetres.

of Temple G to its discrepancies of measurement, the following points are instructive. An extreme ultimate disparity in columnar diameters of 12 inches in S. Maria Aracœli at Rome, and an extreme ultimate disparity of 36 inches in columnar height, are wholly unobserved by the average visitor. This disparity escaped my own attention, for instance, in 1895, and at a time when I was engaged in making systematic observations for similar irregularities and had only this purpose in visiting the church.[7] The extreme differences of diameter in the columns of the nave of the Pisa Cathedral (which came from various temple ruins in Sicily) are less than those quoted for Temple G, but variations of 2½ feet in height, as between the two lines of columns in the south transept at Pisa, are wholly unnoticed by the eye. During five weeks' survey work at Pisa, in 1895, not one of our party of three surveyors observed this variation, and I finally discovered it by accident when engaged in plumbing the columns. The man who was carrying the pole from which the plumb-line was suspended could not reach to the top of the columns on the west side of the transept, and in this way I was led to notice the discrepancy and to take measures of it, with the above result. Neither is any visitor to the Pisa Cathedral aware that the average columnar height on the south side of the nave is 20 inches (1.65 feet) greater than the average of the north side. The visitor is not likely to notice that there is a variation in *adjacent* columns on the south side of the nave of 21½ inches (1.79 feet), and the visitor is certain not to notice that the maximum discrepancy in the height of the capitals on the south side of the nave *is 53 inches,* or 4.41 feet.[8]

All these variations of size, and much greater ones, are found in normal perspective, and the eye, which never sees actually equal dimensions as actually equal, unless at equal distances from them, therefore does not take note of irregularities which actually exist between presumably equal things, because these irregularities are attributed to the normal optical variations of size. The great variations above mentioned are, therefore, discounted by what may be termed the natural physiology of vision. There is no doubt that variations in columnar height are more easily perceived than variations in columnar diameter, and since these variations of height generally pass unnoticed at Pisa, and are certainly never realised as regards their great amount, we may draw some conclusions as to the effect of the variations in Temple G. As far as the very considerable variations of columnar diameter in the Pisa Cathedral nave are concerned, they are absolutely inconspicuous.

The study of the mediæval asymmetries may thus assist us to realise

Figs. 100, 101. Drums of a Shaft. Inverted Doric Capital and Abacus.

Ruins of Temple G, Selinus. Brooklyn Institute Museum Series of 1895.

that, however surprising the existence of the asymmetries in Temple G may be, they were still not conspicuous or obtrusive features.

This temple also offers a remarkable analogy to the freedom with which changes of plan and detail were made during the construction of a mediæval cathedral. It also offers a parallel to the mediæval toleration of variations of dimension which were primarily due to the use of heterogeneous materials, as just described for the Pisa Cathedral.

From these points of view we are now led to return to the Hera temple at Olympia, of which Professor Dörpfeld remarks that the variations of columnar diameter are now quite conspicuous. This is certainly due to the fact that only the lower drums of the columns are in position, generally speaking, and that in many of these the top of the drum is below the level of the eye (Figs. 91, 93, 94, pp. 161, 163). For this reason the discrepancies of diameter must be much more conspicuous now than they were originally. It is evident that variations of diameter must appear relatively greater when the given cylindrical form is relatively shorter. When the temple of Hera was seen as a complete structure, the discrepancies of diameter must therefore have been far less noticeable.[9] It is also a matter of course that the variations of columnar dimensions as between the flanks and the fronts of the Olympian Hera temple would be imperceptible in actual perspective, and could be detected only by close examination at short range.

By the analogies between the Olympian Hera temple and Temple G at Selinus, we are now led to consider more closely Professor Dörpfeld's theory that the discrepancies of columnar diameter at Olympia are due to successive substitutions of stone columns for wooden ones. Admitting that these substitutions actually occurred—and this may readily be admitted—they could not explain why the original wooden columns were unequal, they would not explain why a more advanced taste had not corrected this inequality, if it existed, and they would not explain why the columns and spacings of the fronts are systematically larger than those on the flanks. Finally, we are now aware of similar discrepant dimensions in Temple G at Selinus for which no timber-column theory is possible, and which are not only actually greater but also *relatively greater* than those at Olympia. The greatest discrepancy of size at Olympia is about one fourth of the minimum diameter, but the greatest discrepancy at Selinus is about one third of the minimum diameter.[10] Professor Durm has already pointed out that the discrepant columnar dimensions of Temple G at Selinus, as previously observed by Hittorff, tend to discredit the debated explanation of the irregu-

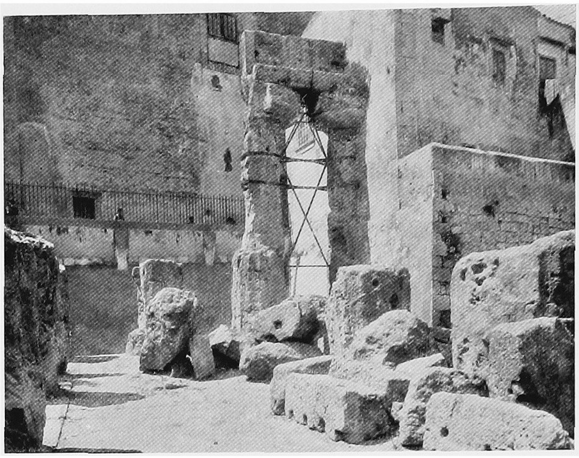


Fig. 102. Ruins of the Temple of Apollo on the Island of Ortygia, Syracuse. Sixth Century B.C.

larities at Olympia, viz., that they have resulted from substituting stone columns for wooden ones. His own explanation of the asymmetries of the temple of Hera is as follows: "A peculiarity of the columnar arrangements has still to be noticed: that, strange to say, it did not offend the Greek sense of beauty to allow columns of quite unlike form in the same building and often side by side."[a] This appears to be the inevitable and highly suggestive conclusion, as is demonstrated by many Sicilian temples.

Thus, although wooden columns may have preceded the stone columns at Olympia, the fact cannot be quoted as a satisfactory explanation at Olympia, because still greater discrepancies were tolerated at Selinus, with the same equanimity, and without the same cause. Moreover, the following details will show conclusively that the Hera temple at Olympia is very far from being an isolated instance of asymmetry. On the contrary, this temple is representative and typical for a number of others. Not only are its heterogeneous asymmetries paralleled or exceeded in Sicily, but the systematic variations at Olympia, as between flanks and fronts, have also a multitude of parallels. Both of these points will be made apparent by a quotation of measurements for other Sicilian temples.

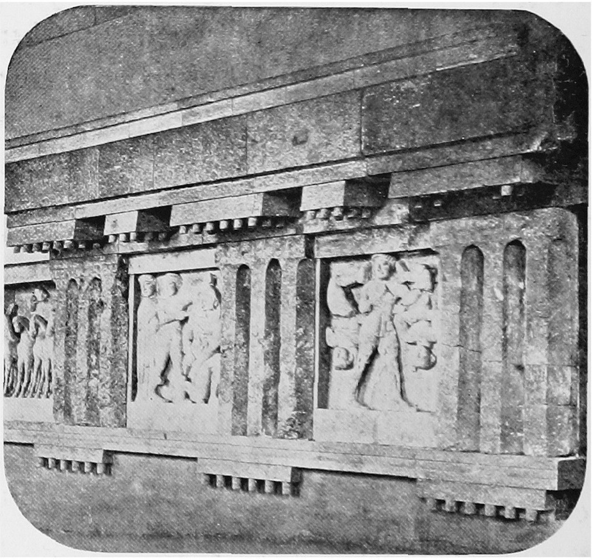


Fig. 103. Metope Reliefs from Temple C, Selinus. Early Sixth Century. In the Palermo Museum.

For instance, in the Apollo temple on the island of Ortygia at Syracuse (sixth century), the monolithic angle columns, *on the same front,* differ by a foot (30 cm.) in diameter.[11] No mediæval heterogeneous variation could be bolder than this.

[a] "Einer Besonderkeit ist bei den Säulenstellungen noch zu gedenken: dass es merkwürdigerweise das Schönheitsgefühl der Griechen nicht verletzte am gleichen Baue, oft nebeneinander, Säulen von ganz ungleicher Form zu dulden." *Baukunst der Griechen* (third edition, 1910), p. 257.

Still more surprising and interesting facts which parallel the asymmetries of the Olympian Hera temple are obtained from Temple C at Selinus. This is the imposing sixth-century ruin (within 23 feet as long as the Parthenon) to which the famous archaic metope reliefs now in the Palermo Museum belonged. For instance, the columnar diameters on the north flank of this temple show a maximum variation of 8½ inches, or 22 cm.[12]

However surprising such facts may be, in view of our prevailing ideas about the symmetrical regularity of the Greek temples, it must still be admitted that the use of heterogeneous columns from older temples may have caused these asymmetries, and that they must therefore be classed as tolerated irregularities.[a] The opinion of the surveyors is, however, very definite, that these and other irregularities were not due to modifications during construction (as they were in Temple G), or to successive repairs at

[a] The special difficulties which beset this theory are mentioned in Appendix[27]. On this point it may also be remarked that at least five columns, and perhaps six, have twenty flutings, whereas the others have sixteen flutings.

Fig. 104. Ruins of Temple C, Selinus. Early Sixth Century B.C. Compare Fig. 90, p. 160.

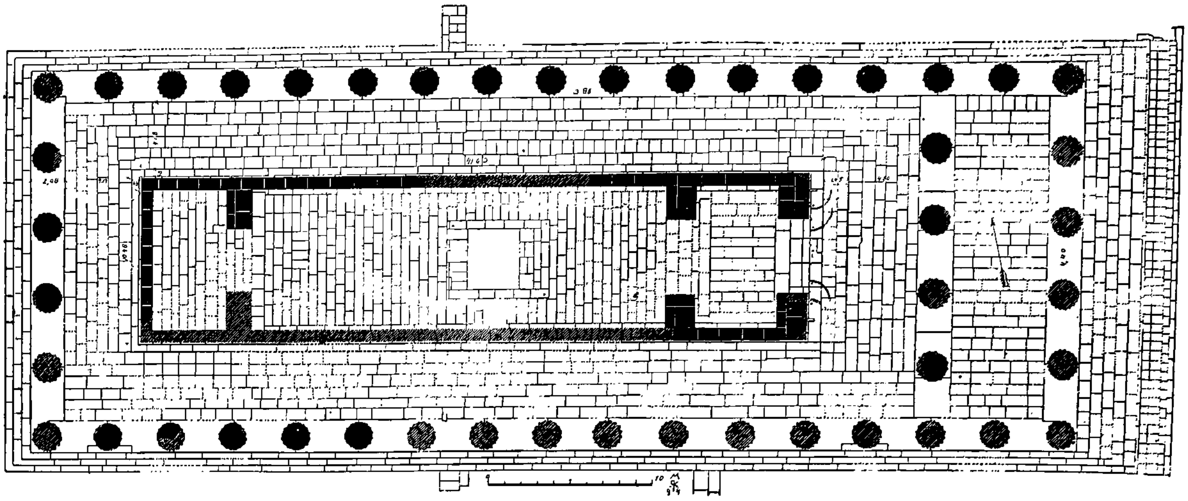


Fig. 105. Ground-plan of Temple C, Selinus. From Koldewey and Puchstein.

The columnar diameters are 3¼ inches larger on the fronts than on the flanks; the intercolumniations are 22 inches wider on the fronts than on the flanks. See Appendix[26] for measures in detail.

different periods (as they were supposed by Dörpfeld to have been at Olympia). On this point the surveyors express themselves as follows:

> Such points as have otherwise been urged [*i.e.*, by other authors], to the effect that important parts of the temple are of different periods, either as the result of entire reconstruction or of a radical restoration, or as the result of taking the materials from an older building, are not sufficiently important to alter our conviction that the framework of the building was executed as a homogeneous whole which has only undergone changes in the final completion.[13]

As contrasted with these above-mentioned unsystematic but extremely interesting variations, the columnar diameters at the front and rear of the temple are *uniformly larger than those on the flanks,* with an average increase of 3¼ inches, or 8 cm., for each column. Here is a palpably purposed variation of dimension.[14]

Similar disparities of individual measures and the same uniformity of general variation, as between the fronts and flanks of Temple C, are found in the intercolumniations. The irregular variations of intercolumniation on the north flank have a maximum of 8 inches, or 20 cm.; but there is also a uniform variation in the intercolumniations at the fronts when compared with the flanks, involving an average increase, *in each spacing, of about 22 inches,* or 55 cm.[15] Thus we have here a parallel to the systematic variations of the Olympian Hera temple, to which many others will presently be added.

It is also pointed out by the surveyors that the proportions of the plan of Temple C are commensurate within 3 inches (8 cm.), giving a length of just four times the width, with that amount of error. The surveyors also mention that the intercolumniations on the fronts and flanks might have been planned for a much closer equality by placing 16 columns on the flanks instead of 17. (The present relation is 6 front and 17 side—angles counted both ways.) Their conclusion is that "the narrower intercolumniations on the flanks as compared with the fronts are not caused by any inadequacy of the ground-plan, but represent *a predetermined variation* in the intercolumniations."[16] Another passage of the same work says, in discussing the general subject of the Greek temple asymmetries: "If the architect of Temple C had had the least interest in the equality of his intercolumniations, he could easily have made their measures more nearly alike than he actually did."[17]

The instance of Temple C at Selinus is not isolated. It represents a system of which numerous temples offer examples. These are the more interesting because some of them show systematically wider intercolumniation on the fronts, while others have systematically wider intercolumniation on the flanks. This alternation between two different arrangements of systematic asymmetry shows that neither system was called for by utilitarian or practical considerations, as, for instance, the convenience of wider openings opposite the temple doors. Other systems corresponding to that of Temple C will, however, be mentioned first.

The plan of the Apollo temple, on the island of Ortygia, near Syracuse, has an average greater width of intercolumniation on the fronts, as compared with the flanks, of 18 inches, or 45 cm.[18] The Zeus temple near Syracuse (sixth century) has a similar greater average in spacing on the fronts of 13 inches, or 33 cm.[19]

So far it might be assumed that the convenience of wider openings at the entrances would explain these variations, but the surveyors discredit this possible presumption by measurements from the following temples. The so-called Basilica at Pæstum, now known to have been a sixth-century temple, has the wider intercolumniations on the flanks, with an average increase for each spacing of 9 inches, or 23 cm.[20] The same arrangement is found in the sixth-century Temple D at Selinus, with an average increase on the flanks of 5½

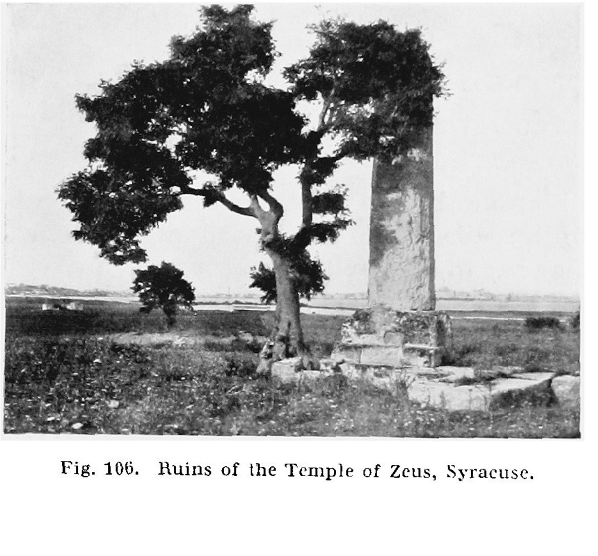


Fig. 106. Ruins of the Temple of Zeus, Syracuse.

Fig. 107. Ruins of Temple F, Selinus (Sixth Century), looking South toward Temple E.
Brooklyn Institute Museum Series of 1895.

inches, or 14 cm.,[21] and in Temple F at Selinus (sixth century), with an average increase on the flanks of 5 inches, or 12 cm.[22] Temple G at Selinus, the sixth-century Greek temple at Pompeii, and the sixth-century Greek ruin near Metaponto, popularly known as the Tavole Paladine, are also mentioned for minimised phases of the same peculiarity.[23]

The remarks of the surveyors as to the evidences of purpose in the instance of the Basilica at Pæstum are of the greatest interest, because the margin of mason's error in axial spacing on a given side or front is mentioned as not exceeding 6 cm., or 2¼ inches. After describing the various proportions and measurements of the ground-plan our authors continue as follows:

Thus, in the case of this ground-plan, there was certainly no question of making the difference between the front and side bays as small as possible; because, if the length of the cella had been divided into 11 parts, instead of 13, the result would have been a side bay of 5 4/7 [units] and consequently very closely equal to a front bay of 5 4/8 [units]. Such a result was, therefore, not intended by the architect. It was, on the contrary, exactly the purposed emphasis on the differentiation of the intercolumnar spacings which controlled him, and by means of the distribution of the spaces, which was found desirable, the side bays are brought into a proportional relation with the front bays, and in the simple ratio of 11 : 12, or 5½ : 6.[a]

[a] The original passage is quoted in Appendix[20].

We may now return to Professor Dörpfeld's publication on Olympia, in order to quote from his unerring pen some facts which rise to really remarkable significance when they are related to the more numerous, and therefore more suggestive, facts which have been so recently made known for the early temples of the western Greek Colonies.[24] Professor Dörpfeld is authority for the statement that the intercolumniations are 12 inches, or 30 cm., wider on the fronts than on the flanks of the temple ruin at Corinth (early sixth century); and that the older Parthenon (sixth century) had the same systematic asymmetry to the amount of 8 inches, or 20 cm.[a] These statements are supplementary to his account of this same peculiarity in the Zeus temple at Olympia, where the greater amount of axial spacing on the fronts is reduced to the astonishing refinement of 2 or 3 cm. excess; that is, from ¾ of an inch to 1¼ inches excess for each intercolumniation.

Professor Dörpfeld also expressly guards against the inevitable suspicion that such a variation must be accidental, and is thereby led into a most interesting description of the method by which the Greek builders were able to attain such accuracy in purposed minute variations that the limit of mason's error in the Olympian Zeus temple was not greater than a centimetre, or less than half an inch.[25]

Dörpfeld thus ranges himself with Penrose, who, on wholly different grounds, had reached the conclusion that the margin of mason's error in the Parthenon is 0.022 foot, or ¼ inch (p. 10).

We are now able, by uniting the facts quoted from Dörpfeld with those obtained from Koldewey and Puchstein, to formulate some deeply interesting results. In the sixth-century Temple C at Selinus, a purposed average variation of intercolumnar spacings, as between fronts and sides, of 22 inches for each spacing, was reduced in the fifth-century Zeus temple at Olympia to a little more or less than one inch for each spacing, or from 55 cm. to 2 or 3 cm.! Truth is certainly stranger than fiction. And yet the same refinement of systematically asymmetric dimensions was in question.

Moreover, the measurements quoted in these pages, including those for the temple at Corinth and the older Parthenon, show every possible grade of intermediate variation between these extremes. Thus we are led to observe the sequence in time and in evolution which explains this great contrast in variations of measurement which belong to the same system of purposed asymmetry.

On this head many proofs and illustrations are given by Koldewey and Puchstein for the gradually diminishing amount, according to sequence of

[a] Penrose (p. 6) also quotes these variations for the older Parthenon and the temple at Corinth.

time, both of the unsystematic and of the systematic asymmetries of Greek temple-planning. It is a well-known law of all historic art evolution that, in each of its epochs, the formulas of mechanical perfection tend gradually to supplant the freedom and *sans-gêne* of primitive art. These authors rely, in fact, for much of their dating on this law of sequence, and by recalling it here, as related to the culmination of Greek art in the Olympian Zeus temple and in the Parthenon, and to the relative decadence which began immediately after their completion, we find a marvellous interest in the minute refinement of the space-widening on the fronts of the temple of Zeus at Olympia.

As regards the unsystematic variations of dimension in the early Greek temples, there are still further facts of interest to be quoted from the same surveyors. So far the north colonnade of Temple C at Selinus has been the main illustration of these features;[26] for although the great irregularities of Temple G are unsystematic in a certain sense, they were, notwithstanding, inspired by a definite movement of taste in the sequence of architectural

Fig. 108. Ruins of the Temple of Zeus, Olympia. About 456 B.C.

development. Moreover, it may be possible, although our authority does not suggest it, that heterogeneous columns from older temples were used in Temple C.[27] This explanation could not, however, apply to the triglyphs and metopes of the entablature of the same temple.

It is recorded of these that "they are broader on the fronts than on the flanks, but are very irregular where one is compared with another," and that they vary "on one and the same side from 12 cm. to 14 cm."—*i.e.*, from 4¾ inches to 5½ inches.[28] A very casual inspection of the Koldewey and Puchstein measures will show that what they call "the usual irregularities" include unsystematic variations in intercolumniation of 8 cm. in the Apollo temple at Syracuse, of 6 cm. in Temple D at Selinus, of 10 cm. in Temple F at Selinus, etc. Thus the tolerated and unsystematic irregularities in Greek Sicilian temple architecture of the sixth century, aside from the north colonnade of Temple C, where they rise to a maximum of 8½ inches, vary from 2½ to 5½ inches.

The fact thus stands out in bold relief that both *systematic and unsystematic irregularities are found in the same Greek temples.* Therefore we obtain a foothold and parallel for demonstrations in later volumes of these studies that *the existence of unsystematic irregularities of dimension, in a given mediæval cathedral, does not preclude or discredit the existence of systematic irregularities in the same cathedral.*

Moreover, the surprising point can be made that the irregular variations in early Greek architecture are fully as great as those which usually occur in mediæval churches.

It can be abundantly proven that three or four inches is a very liberal allowance for mason's error of measurement, or laying out, in mediæval building. Some of these proofs may be mentioned here. In Wells Cathedral the extreme variation in corresponding bays on opposite sides of the nave is one inch (0.08 foot). There are only two bays, out of the total nine, in which the variation is over ⅜ of an inch (0.03 foot). The extreme variation in eight sequent bays is 1¼ inches (0.10 foot).[29] The limit of avoidable mason's error in some parts of the Pisa Cathedral is not greater than ⅜ inch (0.03 foot).[30]

Perhaps the most interesting comparison between sixth-century Greek work and some of the mediæval masonry is offered by the variations of arcade spacing in S. Piero in Grado, near Pisa, because this well-known pilgrimage church is unquestionably the most ancient and the most roughly built of the extant churches in the Pisan province. The greatest mason's error in adjacent pilaster spacings on the north exterior wall of this church, which is very rough masonry, is less than 2 inches (0.16 foot). The extreme variation is 3½ inches (0.30 foot).[31] When all the elements of the problem, and especially the high perfection of the sixth-century Greek temples in other particulars, are considered, it must be admitted that the tolerated asymmetries of dimension are even more remarkable in Greek work than in that of the mediæval builders.

It remains to be mentioned that the surveyors who have established the facts described in this chapter for the Greek temples of the Western Colonies are themselves thoroughly astonished by them. One of their chapters, which is devoted to a summary of general results, is entitled "Characteristics of Ground-Plan" ("Grundrisseigenschaften"). From this chapter the following passages are taken:

> If we consider the details of the peristyle, it is, in the first place, very surprising that, in numerous temples of the older group, the intercolumniations are of different widths on the fronts and sides. . . . What may have led the ancient architects to an arrangement which appears to us moderns as being of a highly extraordinary character *we do not know*. . . .

Of the unsystematic irregularities these authors say:

> That all this was treated in such extremely irregular fashion must really fill us with astonishment. It can only be partially explained by the unusually careless execution of those temples.[32]

The only, and confessedly tentative, explanation which is offered by these surveyors is that of "a total apathy toward the idea of regularity."[33] It must, however, be admitted that whereas "apathy" might explain toler-

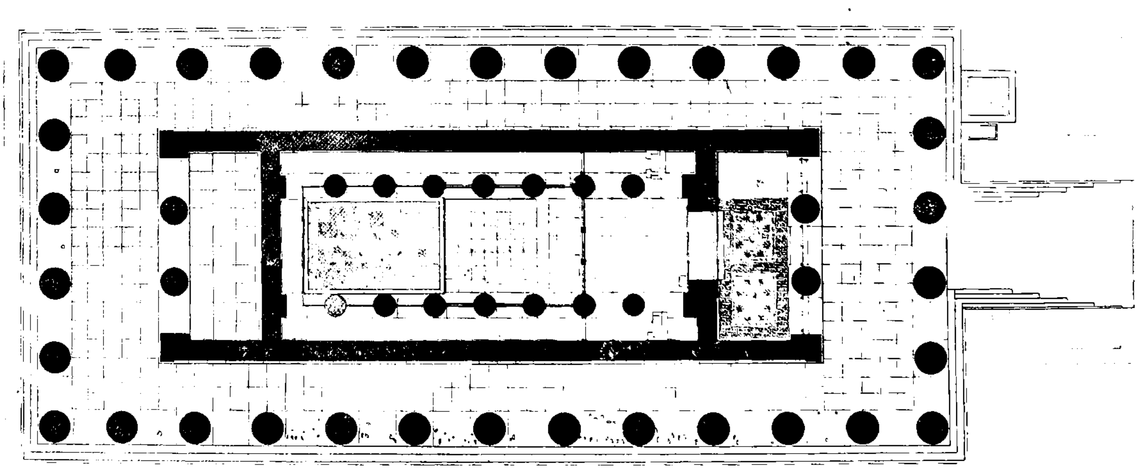


Fig. 109. Ground-plan of the Temple of Zeus at Olympia. From "Olympia: Die Baudenkmäler."

The axial spacing is ¾ inch to 1¼ inches greater on the fronts than on the flanks, excluding the angles; the spacial contraction at the angles is 18½ inches on the flanks and 17¾ inches on the fronts. See Appendices[25] and [38].

Fig. 110. The so-called Basilica at Pæstum, a Sixth-century Greek Temple.

ated irregularities, it cannot explain those which are predetermined and carefully planned. The difficulties which beset our authors will hardly exist for those who have patience to undertake the perusal of later volumes of this work. It need only be said here that a most interesting parallel to mediæval problems is offered by the researches of Koldewey and Puchstein, and that either series of facts, whether for Greek or for mediæval building, corroborates and explains the other series.[34]

There is, however, one passage in the work of these surveyors, in the chapter which is devoted to the Basilica at Pæstum, which *does* venture into the field of æsthetic criticism as to the differentiation in that temple of the intercolumnar spaces. The authors are discussing the dating of the ruin as being somewhat obscured by the lack of reliable measurements above the surface level (see p. 129). They then continue:

> However, the ground-plan is sufficient to give the building its place at the close of the early period. It is, indeed, limited by that wavering method of the old free style, as dependent on the individual point of view, and yet it crowns it in a wholly definite direction *by the emphasis on the differentiation of the bays.* It is true that one could never have reached [by that road] the method of the strict Doric style, which rests on the balance between the bays and the triglyphs. However, *the certainly justified emphasis on the distinction between the fronts and sides and the predetermined proportional relation between these two main divisions of the peristyle give the building a self-assured security which is considerably increased by the unusual ornamental handling of the capitals.*

Although this point of view does not reappear in the chapter which is expressly devoted to a résumé of this particular subject, and is not otherwise found in any part of this work, this passage acquires singular importance from one consideration. *With one exception, the only Greek temple ruin in existence where the effect of the intercolumnar space differentiation as between fronts and sides can now be studied is this particular one.*[a] Let the reader run through the list of temples which have been quoted for this class of facts, and compare them with the illustrations of these ruins which have been largely supplied in these pages. The Tavole Paladine, near Metaponto (Fig. 114, p. 191), is the only other ruin of the whole series, with differentiated flanks and fronts, which has any portion of the colonnade now standing, and all of the columns in this instance belong to the sides.

Thus we may presume that the favorable judgment of Koldewey and Puchstein as to the effect of this arrangement in a building where it can still

[a] The temple of Poseidon at Pæstum has a space differentiation between fronts and flanks of one inch, but has not been quoted by K. and P. as an instance of the system. See p. 188.

be studied, is of more significance than their conservative agnosticism as to the motive of the same arrangement in the multitude of ruins where only the measurements have been recovered and where the effect cannot be seen. The translated passage is, therefore, of such importance as to warrant quotation from the original in Appendix[35].

THE variations of dimension which have been so far described in this chapter preceded in order of time the system of spacial contraction at the angles of the temple porticoes, as found in the Parthenon and in many other temples, where it was connected with the problem of the angle triglyph

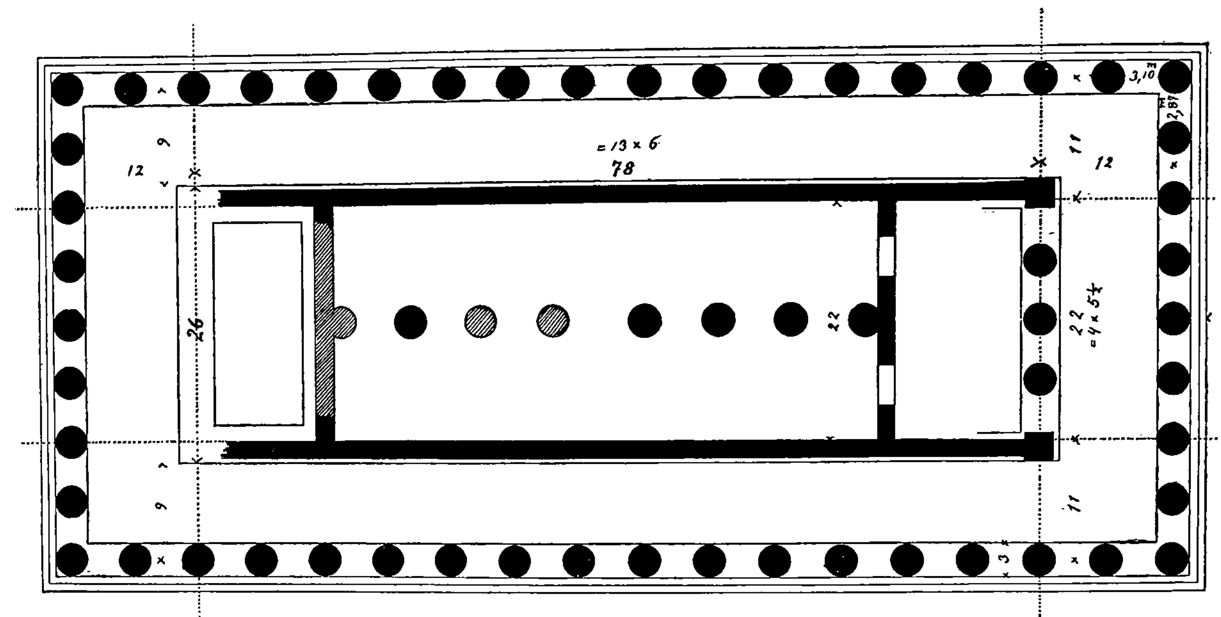


Fig. 111. Ground-plan of the Basilica at Pæstum. From Koldewey and Puchstein.

The intercolumniations average 23 cm., or 9 inches, greater width on the flanks than on the fronts. The margin of mason's error is 2¼ inches.

(p. 20). In the Doric temples of the fifth century the architects endeavored to achieve an approximate symmetry in the relative positions of the triglyphs and columns, so that the triglyphs, which are double the number of the columns, might appear alternately nearly over the centre of the column and nearly over the centre of the intercolumnar space. Inasmuch as the triglyphs are much narrower than the abaci of the columns, the angle triglyph, if placed with exact symmetry over the angle column, would be at some distance from the temple angle, which would thus be bare of emphasis where most needed.[a] This would have given an appearance of

[a] This expedient is recommended by Vitruvius. This shows that the Roman Imperial period had lost the appreciation for the significance of the triglyph as a supporting member.

weakness and emptiness to the angle. Therefore the triglyph was placed at the angle, and to avoid the consequent disproportionate widening of the adjacent metope the intercolumniations adjacent to the angle column were contracted. Generally, and in the Western Colonies almost universally, the contraction was distributed, between the two intercolumniations next the angle column, in different amounts. In the Parthenon a single contraction of about two feet was the expedient adopted.

Thus most Greek temples of the fifth century had three different amounts of intercolumnar spacing on each side—the normal measure and the two diversely contracted spaces next the angle column. It will be readily understood that the older Greek asymmetry systems of differentiating the columnar spaces on the fronts and sides could not easily be practised under such conditions, but it is also evident that the artists who had devised and enjoyed the earlier schemes were followed by others who had simply substituted a new system of asymmetry of a more subtle character but equally effective result.[36]

This, at least, is the interpretation of the facts as understood by the writer, and the next chapter will elaborate the point of view on which this interpretation of the facts is based. In advance of this discussion we may note briefly here the dilemma in which Koldewey and Puchstein have been placed by their own interpretation of the facts, which starts from the presumption that a purely formal symmetry of arrangement was the end sought by those architects of the Doric order who introduced the spacial contraction of the angle columns in order to regulate the relation of the triglyphs to the columns and to the intercolumnar spaces.

The conclusion to which these authors are forced is that this effort to regulate the relation of the triglyphs to the columns was a total failure. The opinion is expressed in the most explicit fashion. To quote the words of these authors:

> And what was the real consequence of this struggle for regularity, and of the long conflict about the triglyphs? [It was] that one and the same temple, although built with the greatest precision, had three variations in axial spacings and three variations in metope widths. Here we must really say that the Doric style shot outside the target with great precision.[37]

It appears to the writer, from this and other similar passages, that our authors have confused two contemporary but separate tendencies in the Greek Doric temple architecture—a tendency to greater precision of measurement and a tendency to bring the triglyphs into spacial relations with the columns. It also appears that this confusion is due to their premise that formal regularity of measurement was the desirable ultimate ideal of Greek temple architecture.

Let it, however, be assumed that the Greek builders, in establishing an approximate equality of relation in the arrangement of the columns and the triglyphs, were working for rhythm rather than regularity, and the dilemma disappears. There is an undeniable charm in a Greek Doric temple which is due to the repetition and duplication of the perpendicular effect of the columns on the horizontal line of the frieze. This repetition and duplication are found in the triglyphs, but this rhythmic relation to the columns by no means demands a mathematical equality of corresponding measurements. Because the most desirable position of the angle triglyph made this equality of measurements impossible, it by no means follows that the Greek builders of the fifth century would have considered such an equality desirable if it had been obtainable. There is much about their architecture which points to a contrary conclusion.

It is not wholly without interest in this connection to record here the existence of at least two temples in which the transition from the system of spacial differentiation between the front and flank colonnades, to the system of spacial contraction at the angles as related to the spacing of the triglyphs, is represented *by the presence of both systems in one temple.* If these systems had represented different tendencies they could hardly have been thus combined. The practical difficulties of such combinations were undoubtedly great, and are more than sufficient to explain why the earlier system generally disappeared when the later one was introduced.

One of the ruins in which both systems appear is the temple of Zeus at Olympia, previously mentioned for the delicate variation in the intercolumniations of the flanks and fronts. In this temple the spacial contraction at the angles is 47 cm., or 18½ inches, on the sides, and 45 cm., or 17¾ inches, on the fronts.[38]

The extreme delicacy of the systematic variations of intercolumniation which has been instanced in the Zeus temple at Olympia has a parallel which has all the greater interest because it occurs in another temple in which the system of spacial contraction at the angles is also fully developed. This parallel is found in the temple of Poseidon at Pæstum, which dates about 440 B.C.[a]

The recent surveyors of this temple have shown that the widths of the normal spacings on the flanks are 0.025 m., or one inch, wider than the normal spacings on the fronts.[39] (The "normal" spacings are so called to

[a] See chronological table in K. and P., p. 233.

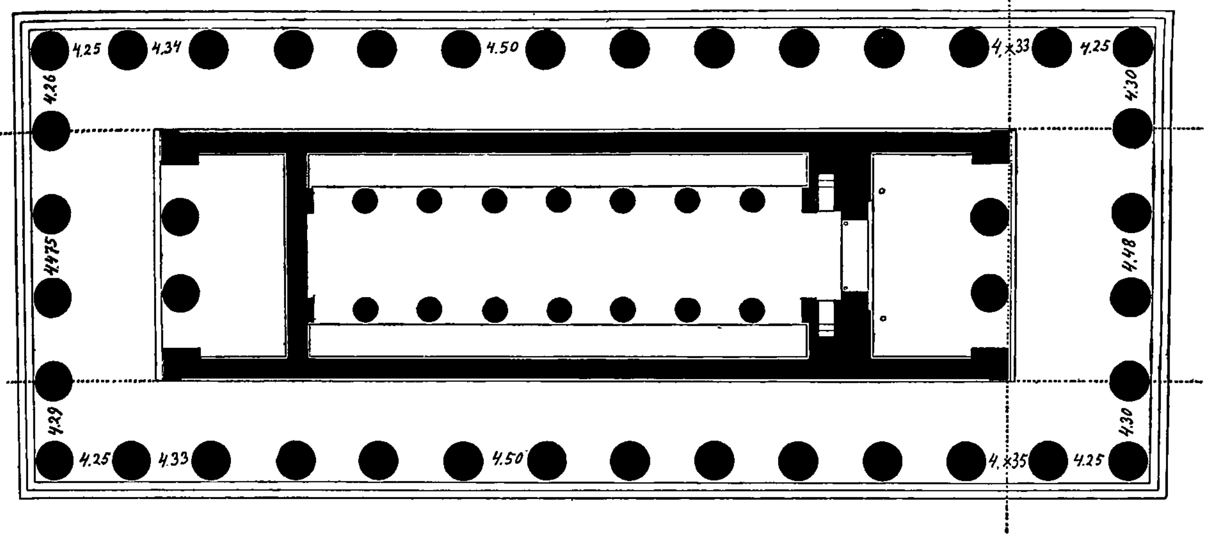



Fig. 112. Ground-plan of the Temple of Poseidon at Pæstum. From Koldewey and Puchstein. The normal spacings on the flanks are an inch wider than on the fronts. The system of spacial contraction at the angles is also illustrated by the plan. There is a two-space contraction on the flanks and a single spacial contraction on the fronts.

distinguish them from the contracted spaces, of which there are two next the angle on the flanks and one next the angle on the fronts.) This fact is mentioned by Koldewey and Puchstein without comment, and is not referred to by these authors in later portions of their work, where the other and numerous systematic variations as between fronts and flanks are described. However, we can hardly avoid placing this instance beside the one which has been recognised by Dörpfeld at Olympia.

However surprising this parallel with the Olympian temple of Zeus may be, it is certain that a remarkable delicacy of masonry construction was attainable in the Western Colonies at a much earlier date than 440 B.C. Thus we are informed that the so-called temple of Ceres at Pæstum, which dates before 510 B.C., has "absolutely equal" intervals, with a margin of mason's error of only 3 cm., or $1\frac{3}{16}$ inches.[40]

As again illustrating the great accuracy of the masonry construction which was achieved before the close of the sixth century, we may quote the columnar spacings of the Greek Doric ruin near Metaponto, known as the Tavole Paladine. This temple, which has a purposed wider columnar spacing on the fronts of 4 cm., or $1\frac{1}{2}$ inches, is mentioned as having a mason's error of only 2 cm., or about $\frac{3}{4}$ inch, the spaces on a given side being exactly equal within the limits of that variation.[41] This temple dates before 510 B.C.

Thus, as such accuracy was attainable in Colonial temples over sixty years before the completion of the Parthenon, we find renewed assurance (were it needed) that the allowance by Penrose of ¼ inch for mason's error in the Parthenon, and the allowance by Dörpfeld of 1 cm., or less than ½ inch, for mason's error in the Zeus temple at Olympia, are trustworthy computations.

Some remarks on the asymmetric dimensions of the Parthenon, which are suggested by the matter of this chapter, will follow here, preceding the conclusion of this volume. This conclusion will return to the subject of the systematic asymmetries described in this chapter, as related to the other proofs furnished by this work that optical corrections were not the special or main purpose of the Greek refinements.

By the preceding notes on Sicilian and South Italian temples we are led to a tentative solution of some problems relating to the Parthenon, for which Penrose did not offer any conclusive explanation, although he was the discoverer of the facts. It was a profound and, in many cases, a reasonable conviction of Penrose that any variation in the Parthenon masonry of more than one fourth of an inch was a purposed, because it was an avoidable, variation. His tendency to seek a theory of correction, and therefore a special cause, for each asymmetry which he discovered may have led him to overlook the possibility that some avoidable variations were tolerated as freehand work; in other words, that some irregularities of dimension, even of the Parthenon, existed because no pains were taken to avoid them, and that no pains were taken to avoid them because the Greeks were good artists.

It cannot be overlooked, at all events, that Penrose established the existence of many variations which are considerably greater than the limit of mason's error which he had determined, and for which his explanations are confessedly wavering and groping. Among these are the irregular intercolumniations (aside from those at the angles as already explained) which rise, in two instances on the north flank, to variations of 0.136 foot, or 1¾ inches. Such variations may be now explained, in consequence of K. and P.'s surveys, as survivals in diminished amount of the older freehand variations, although the masons of the given temple could undoubtedly have avoided them if they had thought it worth while.[a]

As regards the variations in size of the Parthenon capitals and abaci, the increase of size at the angles of about two inches (p. 9) is, of course, connected with the increased size of the angle columns, which are also two

[a] The tentative explanation of Penrose is the same as that offered for the variations of the metope widths. This explanation is considered in Appendix[42].

Fig. 113. The Temple of Ceres, Pæstum. 510 B.C.

inches larger in diameter. This increase of size is generally admitted to be due to the fact that a column, when seen with a background of atmosphere, appears thinner than when it has a background of wall surface.

On the other hand, there are variations in the sizes of the abaci and capitals, aside from those of the angles, which it is impossible to consider as accidental, because these variations are systematic. This is realised by Penrose, who has shown that the capitals of the east front are the largest; that they gradually, but somewhat irregularly, diminish on the north flank toward the west; that the average size on the west front is still smaller; and that the smallest capitals are on the south flank, although the average difference there, as compared with the west front, is not important.

The extreme average difference between the capitals on the east front and those on the south flank is 0.187 foot, or 2¼ inches. The average size on the west front is 0.178 foot, or 2 inches, less than the average on the east front; and a gradual decrease from east to west is found on the north flank, although in somewhat broken sequence.

Mr. Penrose suggests that these changes are due to the varied conditions of lighting on the different sides of the temple, or to the changed position of the spectator on the various sides, as due to differences in the surrounding level. From this point of view, the changes would have been accommodations aiming at a more uniform effect. It appears more likely that a larger or smaller size of capital was considered preferable after one front of

Fig. 114. The Tavole Paladine, near Metaponto. Sixth Century B.C.

the colonnade had been finished, and that this improvement was obtained by a graduated change of dimensions on the north flank. As the general evolution of Greek taste was in the direction of changing the older, flaring, and heavily projected Doric capital to a type having a relatively smaller projection,[a] we may presume that the east front was the first to be finished, and that a slightly smaller capital was considered preferable after these columns were set up. Thus the size ultimately preferred would be that found on the west front and on the south flank, and the transition from one size to the other was carried out on the north flank.

Mr. Penrose has himself alluded (p. 16) to the change of taste, which gradually abandoned the more flaring Doric capital, as a concomitant motive for the mentioned changes of size, and there is no reason why we should not presume it to have been the only one. The average measures for the variations in size of the abaci and capitals are found on pp. 15 and 16 of his work.

The metopes of the east front of the Parthenon show a systematic though somewhat irregular diminution in width from the centre toward the angles, with a total variation, on each side of the centre, of four inches. (The metope measures for the west front do not appear to have been taken.) The tentative explanation offered by Mr. Penrose (p. 17) appears quite inadequate. That of Hauck is more attractive. He presumes it to be an "echo," or repetition, of the effect produced by the spacial contraction of the columns at the angles.[42]

There is no doubt that these variations of dimensions are an improvement to the general effect of the Parthenon, and the point to be especially considered is that, in the Parthenon as in so many mediæval buildings, there is a combined result of optical interest, partly due to purposed, and partly due to tolerated, asymmetries; and that the toleration of asymmetry was an expression of the same artistic spirit which devised the definitely planned refinements.

[a] Compare Fig. 101, p. 171, with Fig. 42, p. 68.

# APPENDIX. CHAPTER VI

[1] See *Olympia* (Berlin, Asher, 1892, Behrend & Co., Successors). The observations are by Professor Wilhelm Dörpfeld, director of the Imperial German Archæological Institute at Athens. Out of 18 capitals, 12 are of distinct types. The depth of the flutings varies remarkably. There is a maximum discrepancy in columnar diameter of 3 inches, or 8 cm., on the fronts (the greatest variation on the plan is 1.28 m.–1.20 m.); and of 9½ inches, or 24 cm., on the flanks (the greatest variation is 1.24 m.–1.00 m.). Without considering the variation in spacing at the angles, for which special considerations relating to the triglyphs are in question (pp. 20, 186, 187), there is a maximum variation in axial spacing of 5½ inches (14 cm.) on the fronts (3.65 m.–3.51 m.), and of 4 inches (10 cm.) on the sides (3.30 m.–3.20 m.).

Aside from these apparently heterogeneous irregularities *there is a purposed average increase* of 5½ inches (14 cm.) in the columnar diameters of the fronts as compared with those of the sides, and a corresponding purposed average increase of 11½ inches (29 cm.) in each of the columnar spacings on the fronts. Text, Vol. II, pp. 27–36.

[2] Aside from the systematic variations of measurement which would be quite sufficient to establish the intention, there is also an increase of width of 9 cm., or 3½ inches, in the stylobate of the fronts, in order to prevent the front porticoes from being narrowed by the increase in the thickness of the columns (stylobate on the sides, 1.34 m. wide; fronts, 1.43 m. wide). The fact is mentioned by Dörpfeld "as a proof that the difference between the columns on the various sides of the temple was intentional." *Olympia,* text, Vol. II, p. 28.

[3] The average columnar diameter on the sides is 1.13 m. (with extremes of 1.00 m. and 1.24 m.), and on the fronts it is 1.27 m. (with extremes of 1.25 m. and 1.28 m.). The average axial spacing on the sides is 3.27 m.; the average axial spacing on the fronts is 3.56 m. See text, Vol. II, p. 30, of *Olympia* (there are slight variations in the exact figures as between those found in the text and in the plates of this work).

[4] The temples at Selinus are generally indicated by letters, as the deities to whom they were dedicated have been generally unknown. Temple G is now known to have been a temple of Apollo.

[5] The upper diameters change first from type 2.31 m. to type 2.12 m. (difference, 19 cm.), and then from type 2.12 m. to type 1.92 m. (difference, 20 cm.); total variation, 39 cm., or 15½ inches. K. and P. furnish only the extreme measures of the lower

drums for the first and third types, omitting the intermediate stage. The lower drums of the two extreme types differ 80–85 cm., or 32–33 inches (3.50 m. west end, 2.60 m. east end, are the measures quoted by K. and P., which would give a variation of 90 cm., but I have followed their record).

6 K. and P. quote the varying measures of Serradifalco (17.66 m.) and of Hittorff (16.30 m.), without having been able to supplement or decide between them.

7 The pavement slopes up three feet (2.90 feet) from entrance to choir, and the columns were so selected from various ancient ruins, in gradually diminishing height and diameter, as to discount the rise of the pavement. Thus the columns next the choir are about three feet shorter than those next the entrance, and of correspondingly smaller diameter.

8 This last variation is between the pilaster capital at the entrance (28.80 feet) and the seventh column from the entrance (33.21 feet).

9 It may be added that the extreme discrepancies of diameter are limited to three columns on each flank, which are placed at irregular intervals and which vary among one another only 7 cm. (from 1.00 m. to 1.07 m.), and with extreme variation from the smaller columns of 24 cm., or 9½ inches. Aside from these columns, the extreme variation on the flanks is 4 inches, or 10 cm., which would have been quite imperceptible to the eye when the temple was seen as a whole. Most of the variations are much less than this. The columns on the east front are practically equal, with extreme variation of 4 cm., or 1½ inches. On the west front, where only three diameters are recoverable, the extreme variation is only 8 cm., or 3 inches.

10 At Olympia the minimum diameter on the sides is 1.00 m., and the maximum diameter on the fronts, 1.28 m.; variation, 28 cm., or a little over one fourth of the minimum diameter. (These measures follow the plan, which varies slightly from text, as quoted at the beginning of this chapter.) At Selinus the minimum diameter is 2.60 m., and the maximum diameter is 3.50 m.; variation, 90 cm., or about one third of the minimum diameter. (K. and P. quote the diameters, as above, as giving 80–85 cm. variation.)

11 K. and P., pp. 62–63. S.E. angle, 1.72 m.; N.E. angle, 2.02 m. Other irregularities of diameter "show a tendency to place the thicker columns in front." The systematic variations of columnar spacing in this temple, as between the fronts and the sides, will be mentioned later on in text, and also in Appendix[18].

12 The measurements for the south flank are not recoverable, in many cases, and are much less complete. On the north flank the largest columnar diameter is 1.92 m. and the smallest is 1.70 m. The average diameter is 1.76 m. Thus, one column is 16 cm., or 6 inches, thicker than the average. The complete measures for the north flank of Temple C will be found in Appendix[26].

[13] Page 96: "Was man sonst dafür geltend gemacht hat, dass wesentliche Bestandteile des Tempels zu verschiedenen Zeiten, sei es bei einem Neubau, sei es bei einer durchgreifenden Restauration ausgeführt oder gar von einem älteren Baue entnommen worden seien,[a] . . . ist nicht bedeutend genug um die Anschauung zu erschüttern, dass der Kern des Baues einheitlich ausgeführt worden sei und ausschliesslich in den Vollendungsarbeiten . . . Veränderungen erfahren habe."

[14] See K. and P., p. 99: "The columns on the flanks, in spite of great variations when compared one with another, are visibly thinner than those of the fronts (average 1.81 m., as compared with average 1.89 m.)."

[15] The average intercolumniation on the flanks is 3.86 m. On the fronts it is 4.41 m. The difference is 55 cm. (See p. 98 of K. and P., and Plate XII.)

[16] "Es ist wertvoll sich hierbei zu vergegenwärtigen, dass das geringere Säulenjoch der Seiten, gegenüber den Fronten, nicht etwa eine Unzulänglichkeit des Grundrisses, sondern vielmehr eine *bewusste Jochdifferenzierung* darstellt." (Page 105, Plate XII.)

[17] "Wenn dem Architekten von Tempel C die Gleichheit seiner Intercolumnien an der Front und den Langseiten auch nur im Geringsten am Herzen gelegen hätte, so würde er ihre Masse jedenfalls bedeutend stärker haben nähern können, als er es in Wirklichkeit gethan hat" (p. 197).

[18] Average on the sides, 3.30 m.; average on the fronts, 3.75 m. (p. 62).

[19] Average on the sides, 3.75 m.; average on the fronts, 4.08 m. (p. 66).

[20] Average on the sides, 3.09 m.; average on the fronts, 2.86 m. (p. 13). The margin of mason's error in either one of these averages is mentioned as 6 cm. The following is the original passage at p. 17, which is translated later on in text:

"Es hat sich bei diesem Grundriss also durchaus nicht darum gehandelt, die Differenz zwischen den Front- und den Seitenjochen so gering wie möglich zu machen; denn, hätte man die Cellelänge nicht in 13 sondern in 14 Teilen geteilt, so wäre man auf ein Längsjoch von 5⁴⁄₇ und demnach dem Frontjoch von 5⁵⁄₈ ungemein nahe gekommen. Derartiges lag also nicht in der Absicht des Architekten. Es ist vielmehr gerade die bewusste Hervorhebung der Jochdifferenz die ihn geleitet hat, und durch die für gut befundene Teilung kommt das Längsjoch mit dem Frontjoch in proportionate Beziehung, nämlich in das einfache Verhältniss von 11 : 12, also 5½ : 6."

[21] Average on the sides, 4.51 m.; average on the fronts, 4.37 m. (p. 108).

[22] Average on the sides, 4.60 m.; average on the fronts, 4.48 m. (p. 118).

[a] References here to Cavallari and Hittorff.

[23] K. and P. At pages 196–197, these temples are included in the general remarks on this topic. The references for details are as follows:

Temple G at Selinus (p. 124) was planned to have spacings which are 10 cm., or 4 inches, narrower on the fronts (east end, 6.52 m.; flanks, 6.62 m.). At a later date, when the west front was finished, a spacial contraction at the angles of that front was introduced, with measures of 6.28 m., and the other spaces were increased to 6.62 m. and were thus made equal to those of the flanks.

The Doric temple at Pompeii (dating about 570–554 B.C.) has a wider spacing on the fronts of 10 cm., or 4 inches (2.54 m. on the sides, 2.64 m. on the fronts).

In the Tavole Paladine, near Metaponto, the spacings on the fronts are 4 cm., or 1½ inches, greater than those on the flanks. The measures and references for this temple are mentioned in Appendix[41].

[24] Aside from contributions to archæological journals by Cavallari and Patricolo, mainly published in Sicily and not generally accessible, and from Serradifalco's *Antichità di Sicilia* (1834), the main authority for Sicilian temples has hitherto been Hittorff and Zanth, *Architecture Antique de la Sicile* (1827, without text; 1870, with text). In spite of its great value in other particulars, this work is now wholly displaced, as regards measurements, by the work of Koldewey and Puchstein.

A sumptuously illustrated French work, wholly devoted to Selinus, appeared in 1910: *Sélinonte,* by Jean Hulot and Gustave Fougères (Paris, Massin).

[25] "In contrast with the old Doric temples of the sixth century, in which this difference is sometimes very great—for example, 0.20 m. in the old Athena temple on the Acropolis, and 0.30 m. in the temple at Corinth—the difference is lowered in the Zeus temple to 0.02 m.–0.03 m. We might suppose this slight difference to have resulted from mason's error, or from accidental displacement during the course of later centuries. That this is not the case is proved by an exact examination of the ruin. In erecting the temple the centres of the columns, and the axial spacings therewith connected, were determined with great care, as can best be apprehended from the following instructive technical peculiarity. Since the 'poros' stone of which the stylobate is built did not have a smooth surface, and the [axial] centres could not, in consequence, be accurately determined, a hole of about 5 cm. in diameter was worked in the 'poros' stone, at about the point where the [axial] centre of the column would lie. This was filled with lead. After the lead surface had been smoothed, the axial centre was indicated by two lines intersecting at right angles, which were scratched in the lead and their intersection was marked as the exact axial centre of the column by a small round hole." *Olympia,* text, Vol. II, p. 6. An illustration accompanies this explanation which is reproduced in Fig. 115.

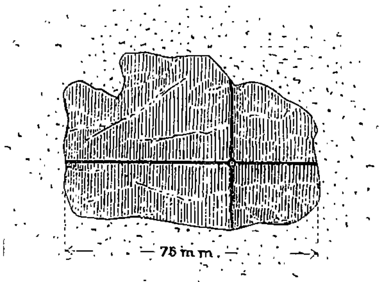



Fig. 115. From Dörpfeld's illustration in "Olympia." Showing the lead filling in the "poros" platform and the cross lines scratched on the lead to mark the exact axial centre.

[26] The following are the measures for the inter-

columniations and columnar diameters on the north flank of Temple C, in order from west to east (the measures on the south flank are not recoverable in many cases):

INTERCOLUMNIATIONS

3.84 : ? : ? : 3.88 : 3.96 : 3.75 : 3.82 : 3.87 : 3.84 : 3.87 : 3.835 : 3.85 : 3.83 : 3.965 : ? : 3.865

COLUMNAR DIAMETERS

? : 1.82 : 1.79 : 1.82 : 1.84 : 1.79 : 1.92 : 1.84 : 1.82 : 1.82 : 1.70 : 1.77 : ? : 1.77 : ? : 1.77 : ?

VARIATIONS OF ADJACENT INTERCOLUMNIATIONS

? : ? : ? : 0.08 : 0.21 : 0.07 : 0.05 : 0.03 : 0.03 : 0.035 : 0.015 : 0.02 : 0.135 : ? : ?

Greatest adjacent variation of intercolumniation, 0.21.
Greatest extreme variation of intercolumniation, 0.21.
Average variation of intercolumniation, 0.081.
Greatest adjacent columnar diameter variation, 0.13.
Greatest extreme columnar diameter variation, 0.22.

27 This theory has difficulties of its own, because the columns of a Greek temple support a horizontal entablature and must therefore all be of one height. Thus, unless the columns were taken from an older temple of the same height, which would generally also mean of the same size, they must have been reworked, as though they were blocks from the quarry, and the saving of labor under such circumstances could not have been very considerable. The rebuilding of temples was, naturally, usually inspired by the desire to make them larger and more imposing, and it therefore does not appear likely that older columns of the changed height could often have been available for reuse without reworking, aside from very exceptional circumstances.

28 The first quotation is from K. and P., p. 100. The second quotation is from p. 197.

29 The last pair of bays toward the choir have a constructive spacial contraction of 20½ inches (10.83 feet–9.12 feet). The measurements for Wells Cathedral spacings are as follows (in order from entrance to choir, and taken to centres of piers):

Left—10.90 : 10.93 : 10.90 : 10.85 : 10.80 : 10.84 : 10.87 : 10.83 : 9.12
Right—10.90 : 10.92 : 10.85 : 10.86 : 10.88 : 10.87 : 10.87 : 10.86 : 9.12

Similar measurements at Salisbury show, in all bays between façade and transept, an extreme variation of 0.04 foot in parallel bays and an extreme variation of 0.09 foot in sequent bays. The limit of mason's error at Salisbury is therefore 0.09 foot, or about one inch. At Norwich the average error is 0.20 foot or less. There is one extreme error, at Norwich, of 0.39 foot. At Ely the extreme error in parallel bays is 0.22 foot; at Lincoln it is 0.34 foot; at Durham it is 0.08 foot.

[30] The five arcade spacings between pilasters, on the west side of the south transept, measure, in feet and decimals, in order from north to south:

8.85 : 8.86 : 8.86 : 8.88 : 8.87

[31] The measures between pilasters on the north wall of S. Piero in Grado, near Pisa, are as follows, omitting the last arcade, against which another building has been placed:

14.22 : 14.16 : 14.20 : 14.10 : 14.08 : 13.92

Adjacent variations, in the same order, are:

0.06 : 0.04 : 0.10 : 0.02 : 0.16

Extreme variation, 0.30 (or 14.22–13.92).

[32] K. and P., pp. 196, 197: "Richten wir unseren Blick hier nur auf die Einzelheiten der Peristase, so ist zunächst sehr auffallend, dass bei mehreren Tempeln der älteren Gruppe die Joche an den Schmal- und an den Langseiten verschieden gross sind.

" . . . Was die alten Architekten zu dieser uns Modernen im höchsten Masse frappierenden Anordnung veranlasst hat, weiss man nicht. . . . Dass das alles nun anfangs so hochgradig ungleichmässig behandelt wurde, muss wirklich in Erstaunen versetzen. Es erklärt sich nur einigermassen durch die hierin ausserordentlich nachlässige Bauausführung jener Tempel."

[33] "Denn anfangs herrscht eben eine gänzliche Apathie gegen den Gleichmässigkeitsgedanken." (K. and P., p. 197.)

[34] Of the two authors of the wonderfully conscientious publication so frequently quoted in this chapter, Robert Koldewey was the practical architect and surveyor, and is also mentioned in Puchstein's preface as the main author ("Der Hauptverfasser"). Otto Puchstein was the antiquarian student and the authority for literary reference. He also superintended the final revision of the text. In 1898, Koldewey, who is a directorial assistant in the Berlin Museum, was made director of the German excavations in Babylonia.

Otto Puchstein, born in 1856 at Labes in Pomerania, died in 1911. An appreciative but discriminating account of his career, written by Professor H. Winnefeld, appeared in the *Zeitschrift für die Geschichte der Architektur,* Vol. V, No. 2 (1911), pp. 47–52. The author is professor of archæology in the University of Berlin, and second director of the collections of ancient sculpture in the Berlin Museum.

From this generally laudatory appreciation of Puchstein's character and attainments, it still appears that his distinction in various fields of research was more generally apparent in the painstaking and accurate investigation and accumulation of facts, and that he was less active and less successful in generalisation and synthesis.

His disposition to exalt and follow the authority of Vitruvius is mentioned as having sometimes led him into error, but no reference is made, on this head, to the present work. My own acquaintance with Puchstein's contributions to the subject of the Ionic capital corroborates these suggestions of the existence of certain limitations in the outlook of this distinguished scholar.[a]

Following his university years, Puchstein's first well-known activity was devoted, in association with Carl Humann, to the colossal monument of a prince of Commagene at Nemruddagh (upper Euphrates valley). The results of two expeditions to this locality in 1882–3 were published in 1890.[b] In association with Koldewey, portions of the years 1892–3–4 were devoted to the temples of Sicily and lower Italy, with the results which were published in 1899. This was the only large work which Puchstein lived to complete. In the years 1900–04 he was director of the German explorations at Baalbek and on the sites of other Roman ruins in Syria as far as Palmyra. The monumental publication of this research was interrupted by his death. In 1907 he accompanied an expedition to the ruins of the Hittite capital at Boghasköi, in the interior of northern Asia Minor. His publication of this research was completed in manuscript at the time of his death.

From 1883 to 1896, Puchstein was a directorial assistant in the Royal Museum of Berlin, and a Privatdozent in the Berlin University. From 1896 to 1905 he was professor of archæology in the University of Freiburg (in Breisgau). In 1905 he was appointed director of the Imperial Archæological Institute of Germany.

35 "Indes vorläufig genügt der Grundriss dazu, dem Bau seine Stellung am Ende der alten Periode anzuweisen. Er ist zwar in jener schwankenden, vom Individuellen abhängigen Conceptionsweise des alten freien Stils befangen, doch setzt er ihm in einer ganz bestimmten Richtung, durch die Pointierung der Jochdifferenz die Krone auf. Damit hätte man allerdings niemals zu einer Art des strengen dorischen Stils gelangen können, der auf der Ausgleichung der Joche und des Triglyphon beruht. Aber gerade die gewiss berechtigte Betonung der Verschiedenheit von Front und Langseiten und die bewusste proportionale Bindung zwischen den beiden Hauptteilen der Peristase giebt dem Gebäude den Character selbstbewusster Sicherheit, der durch die eigentümliche ornamentale Ausbildung des Kapitells eine bedeutsame Steigerung erfährt." (K. and P., p. 18.)

36 Much space is devoted by K. and P. (pp. 197–200) to the various solutions of this problem in those temples of lower Italy and Sicily which are later in time than those described in this chapter, and to the various methods and amounts of contraction at the angles. The most important result of the researches of these surveyors, as related to the matter of this chapter, is that the temples with variations as between fronts and

[a] *Das ionische Capitell; Siebenundvierzigstes Programm zum Winckelmannsfeste der archæologischen Gesellschaft zu Berlin* (Berlin, Reimer, 1887) was hardly on the level of advanced research of the given date. A much more recent essay, *Die ionische Säule als klassisches Bauglied orientalischer Herkunft* (Leipzig, J. C. Hinrich'sche Buchhandlung, 1907), is a somewhat belated and not wholly satisfactory account of the lotiform origin of the Ionic capital.

[b] *Reisen in Kleinasien und Nordsyrien, beschrieben von C. Humann und O. Puchstein.*

flanks do not, as a class, employ the angle contraction, and that their architects appear to have been indifferent to that apparent and approximate regularity of position in the triglyphs and metopes, as related to the columns, which this angle contraction was devised to produce. As no entablatures of the earlier type of temples (with systematic variations as between front and sides) have survived in position, there is very little definite record as to the measurements of their triglyphs and metopes. In general, however, it would appear that these corresponded, both in their systematic and in their unsystematic variations, to the character of the colonnades below. This is the case in Temple C at Selinus, as already shown by the quotation at p. 181.

[37] "Und was war der wirkliche Erfolg dieses Ringens nach Gleichmässigkeit und des langen Kampfs um das Triglyphon? Dass man an einem und demselben mit der äussersten Sorgfalt gebauten Tempel nicht weniger als 3 verschiedene Axweiten und 3 verschiedene Metopenbreiten erhalten hatte! Da muss man wirklich sagen: Der Dorismus hat mit grosser Präcision an seinem Ziel vorbeigeschossen." (K. and P., p. 200.)

[38] See plan in *Olympia: Die Baudenkmäler,* and Dörpfeld's related text, p. 6, where it is also mentioned that an earlier publication of the same expedition, *Die Ausgrabungen zu Olympia,* is in error as to an increase of the central axial spacing on the fronts.

[39] "Thus the normal bays on the fronts and flanks are equal, as between themselves, but those of the flanks are somewhat larger than those on the fronts (4.475 m., 4.50 m.)." (K. and P., p. 25.) The difference is 0.025 m.

[40] "The columns stand in absolutely equal distances averaging 2.62 m. Variations occur up to 3 cm. . . . On the whole, however, the columns are placed very accurately." (K. and P., p. 19.)

[41] "The columnar spacings are equal (2.92 m. as an average), *with errors of* $\pm$ *2 cm.*" (K. and P., p. 36.) As the fifteen standing columns are all on the flanks, ten on the north side and five on the south side, the surveyors have estimated the axial spacings on the fronts by relating the known number of original columns on the fronts to the known width between the axes of the north and south columns. It thus appears that the axial spacings on the fronts averaged 2.96 m., or 4 cm. more than on the flanks. This temple is specifically mentioned at p. 197 as being one of those in which the systematic and purposed variation as between fronts and flanks is found.

[42] The measurements for the Parthenon metopes of the east front are given by Penrose on p. 17 of his book. He has arranged them in the order from north to south, which is somewhat confusing, as it reverses the natural arrangement from left to right. The measurements, in feet and decimals, as here repeated, are arranged from left to right and from south to north:

4.121 : 4.120 : 4.192 : 4.195 : 4.186 : 4.169 : 4.375 : 4.320 :
4.295 : 4.282 : 4.050 : 4.064 : 4.066 : 4.160

The relations of the Parthenon triglyphs, as regards centring, to the columns and intercolumnar spaces over which they are placed are represented by Penrose on Plates VII and VIII of his quoted work, and on Fig. 116, as regards the southern half of the east front. It appears from these measurements (and from Fig. 116) that, whereas the angle triglyphs are necessarily very much to the left and right of the centres of their corresponding abaci, the triglyphs over the adjacent columns on each side are off centre on the opposite side of the columns. Thus the triglyph over the column next the southeast (left) angle is 0.599 foot, or about 7 inches, to the right of the abacus centre, the width of the abacus being 6.751 feet.[a] The triglyph corresponding to the next adjacent column (third column, angle included) is 0.258 foot, or 3 inches, to the right of the centre of the corresponding abacus.[b] Over the fourth column the triglyph is exactly centred. Similar arrangements are found, in reversed direction, in the case of the four northeast columns and their corresponding triglyphs.

It appears certain that these arrangements were made by designers who were aware that they would contribute to optical interest, from the point of view developed in the next chapter. It may be, however, that Hauck's "echo" theory is not needed and that the diminution of the metope widths from the centre toward the angles is connected with the arrangements bearing on the position of the angle triglyphs, as related to the amount of columnar contraction at the angles which was adopted in this particular temple. It is evident, for instance, that the triglyphs described as being off centre to the right would be still farther off centre if the adjacent metope widths had not been diminished. On the other hand, and aside from this diminution and the question of its motive, Hauck has contributed most important matter to the topic of the Parthenon metopes and triglyphs. He is the only author who has given an explicit account of the facts. These facts are, indeed, found in the plates of Penrose, but are neglected by his text. Thus, Fig. 116 has been reproduced from Hauck's work with the view of illustrating these points. In this drawing, as in that of Penrose, which it copies, the details of the triglyphs are omitted. Thus the drops, or guttæ, of the regulæ are not represented. These regulæ appear directly under the triglyphs and are attached to the lower side of the fillet which separates the architrave and frieze. The details of these regulæ may be observed in many photographs of this volume (notably in Fig. 12, p. 21).

We begin our summary of Hauck's account with the point that the joints of the architrave correspond quite closely to the centres of the triglyphs under which they are found. Next, we notice the spacial contraction of the column at the angle and the position of the angle triglyph, whose centre is far outside the centre of the abacus below it. In order to diminish, in appearance, the resulting displacement, as regards centring, of the next adjacent triglyph, its regula has been shifted to the right.[c] Minute circles or dots which have been placed in Hauck's drawing at the centre of the triglyph and of its shifted regula show that a line drawn through these centres would strike the centre of the intercolumnar space below. Thus the eye is insensibly drawn

[a] Hauck's measurements of this abacus (Fig. 116) show an error of half an inch in the translation of the Penrose foot decimals into centimetres, but I have preferred to use his copy of the Penrose plate as giving a clearer reproduction than the original.

[b] The difference between Hauck's measures of this abacus is 0.0786 m., which is correct.

[c] The triglyph is displaced in order to avoid an excessively wide metope next the angle triglyph.

to the right, and the triglyph, really quite removed from the intercolumnar centring, appears to be near it.

An incredibly subtle additional device is that indicated by the plumb-lines which hang beside the abaci. The three outer abaci are cut obliquely and are sloped sideways as regards their north and south faces. From the measurements of these plumbs in the original plate of Penrose we find that the outer abacus is shifted 0.005 foot to the left. The next abacus is shifted 0.004 foot to the left (on the left side). Thus the triglyph next the angle triglyph is actually 0.009 foot, or ⅛ inch, nearer the apparent intercolumnar centre than the natural regularity of relation between the capital and the abacus would allow. The second intercolumnar space is shifted 0.013 foot, or 3/16 inch, to the left (0.009 + 0.004) by a similar sloping of the abaci. The motive must have been to increase the decentring of the triglyph above this intercolumnar space toward the right, and so to counterbalance the decentring in the opposed direction of the triglyph next the angle triglyph.

These delicate variations of adjustment, which are not mentioned in the text of Penrose, appear to offer conclusive arguments against his avowedly tentative suggestion (pp. 17, 18) that the diminutions of the metope widths are due to the difficulty of quarrying a sufficient number of blocks of the unusually great length needed, and that the architects consequently did the best they could with the longest blocks, of somewhat irregular length, which they could obtain. Certain arrangements, such as those of the shifted regula and of the obliquely cut abaci, are obviously related to the problem of the angle triglyph, and these arrangements are so united with the variations in the widths of the metopes that it is impossible to concede that careful design explains the one and that physical and accidental causes explain the other.

The shifted regula is not found on the north side of the east front. It may be noticed, however, from the quoted measures, that the width of the outer metope is greater on that side. We must therefore suppose that one of these arrangements was considered an improvement on the other after the first one was in position.

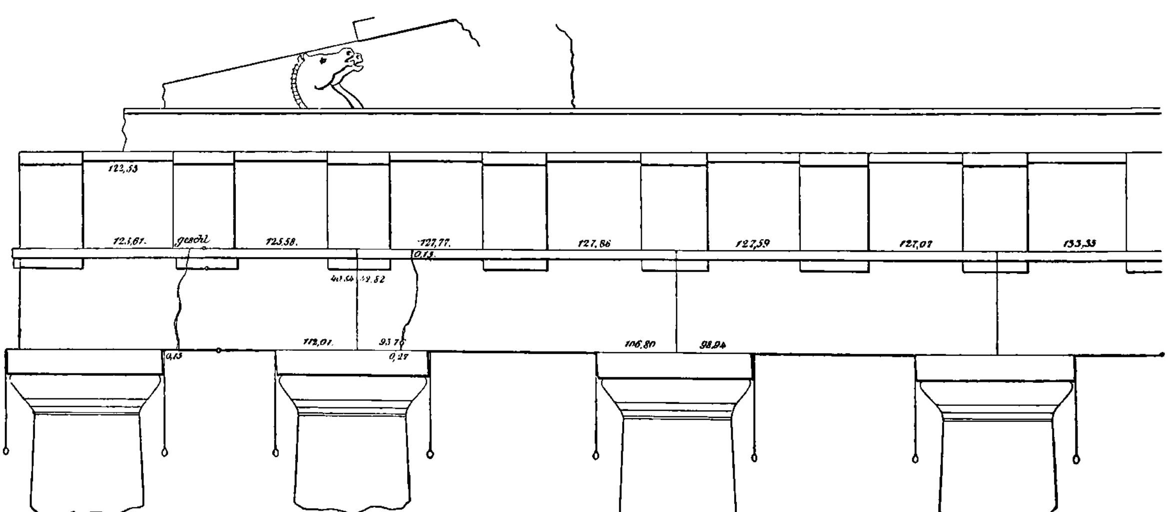


Fig. 116. Metope Measurements for the East Front, South Side, of the Parthenon.

The measurements are in centimetres, but are taken from those of Penrose. The drawing is reproduced from the one published by Hauck and copies that of Penrose.

# CHAPTER SEVEN

## ASYMMETRIC DIMENSIONS IN GREEK TEMPLES, AND THEIR OPTICAL EFFECT

## THE SIGNIFICANCE AND INTEREST OF THE GREEK REFINEMENTS

Fig. 117. Curve of the Entablature, West Flank of the Maison Carrée at Nîmes.

This view shows a strong curvature in the entablature when sighted sideways. This is apparently a curve in elevation, but really an optical effect of the curve in plan. Compare Figs. 27, 28, pp. 43, 45.

# CHAPTER VII

## ASYMMETRIC DIMENSIONS IN GREEK TEMPLES, AND THEIR OPTICAL EFFECT

Although we have found in preceding pages, and especially in our third chapter, abundant proofs that the greatest modern critics have not been wanting in a just appreciation of the optical advantages of the Greek refinements, it must still be confessed that one important point has hitherto been generally lacking in these appreciations. The fact that Greek temple architecture included asymmetric measurements in its general scheme, as a purposed means to optical effect, has been sadly overlooked. It must be admitted also that absolutely conclusive evidence on this head was wanting until the appearance of the admirably conscientious publication to which our preceding chapter is so much indebted.

The authors who have so recently furnished such invaluable material bearing on this question, in the way of matter of fact, have not, however, included in their own point of view the apparently obvious implications of these facts.[a] It may be that their testimony is all the more valuable on this account. Their appreciation of the effect of the intercolumnar variations in the Basilica of Pæstum[b] has, for instance, unusual significance for two reasons: first, because this is, with one exception, the only Greek temple in which the effect of this arrangement can now be observed, and, second, because we are certain that this appreciation was not colored by any preconceived theory as to what the effect ought to be.

The most definite utterance in this matter has been made by Professor Adolf Michaelis, long before these recently accumulated facts were known, in a passage which suggests that the absence of definite ratios in the proportions of the Parthenon may be one explanation of the great optical charm of this temple, to which so many authorities have referred. On this head Professor Michaelis says, in his notable work on the Parthenon:[1]

> The attempt has often been made—for instance, by Penrose—to establish some mathematical formula for the relations of the different parts of the building; but the proportions discovered have been mostly so complicated, and of such various characters in the different parts of the building which have been compared, that it is

[a] See pp. 182, 185. [b] See p. 185.

difficult to consider them as intentional. *Perhaps the fascinating effect* ("der fesselnde Eindruck") *of the general proportions of the building is dependent on the very fact that there are no commensurable measurements in them. In that case this characteristic would fall into line with a numerous series of further observations.* The intercolumniations exhibit considerable variations of width; the heights of the columns, the widths of the abaci, of the triglyphs and metopes, are likewise unequal. This is no imperfection of technical execution, which otherwise shows an unparalleled perfection, and one which was only attainable in the fine-grained Pentelic marble. It is a marvel for architects as well as laymen to observe how the joints of the building, where no special disturbances have taken place, are even now so closely united that it is sometimes difficult for the eye to perceive them.

This passage further continues with a description of the various other refinements, closing with the horizontal curves and vertical inclinations, and including the philosophy of the subject which has previously been quoted from the same authority (p. 91).

At the expense of some repetition of points already largely considered in preceding pages, it has seemed worth while thus to quote Professor Michaelis at this length, in order to emphasise and develop his pregnant suggestion that the incommensurate proportions of the Greek temples may be considered, as regards optical effect, under the same category with their unequal dimensions and intervals, and that all these features are optically attractive to a refined taste in architecture.

A similar view, as regards mediæval building, was held by Mr. Ruskin, who largely atoned for many mistakes and inequalities of artistic judgment by his almost unique perceptions in this direction.[a] My own observations of mediæval Italian churches have included many instances of obviously purposed asymmetric measurements which can have no other explanation than the intentional avoidance of mechanical monotony and the increase of that optical interest which is generally admitted to inhere in variety of architectural detail.[b] Mr. Penrose has himself pointed out in very explicit terms that irregularities of design may be contributory to attractive optical effect. He says, for instance (p. 11): "It has often been noticed that the works of Nature, although usually their tendency is to be symmetrical, are seldom absolutely so; and when, in architecture, exact symmetry does prevail, a dry effect is not unfrequently produced." In fact, this passage precedes the very matter to which Professor Michaelis has referred.

The suggestion of Michaelis will find sympathetic approval on general grounds in many quarters as a matter of æsthetic appreciation, but it rises

[a] See references at p. 161, foot-note[b].

[b] Many of these observations have been published in the *Architectural Record*. See especially the article referred to in foot-note[c], p. 161.

to epoch-making importance when connected with the proofs which are offered in the preceding chapter as to the intentionally asymmetric systems of columnar spacing in Greek temples, because the now widely dominant view advocated by Penrose, that the Greek refinements were intended to correct optical effects rather than to produce them, has offered other explanations of the facts which Michaelis quotes. But the theory of correction loses its last hold when confronted with the ground-plans of the Sicilian temples. There is no doubt that the Greek builders were designing asymmetric intercolumniations in their porticoes, as between the fronts and flanks of their temples, as late as the time of the temple of Zeus at Olympia. (This temple was finished about 456 B.C.)[a] When the measurements which were collated by Dörpfeld on this point (p. 179) are united with those recorded by Koldewey and Puchstein, the evidence is not only overwhelming as regards the facts, but the implications also appear to be unavoidable as to the conclusion to be drawn from them. This conclusion can only be that optical interest was the purpose of these variations.

It appears probable that an optical vibration, or "confusion of the eye," to use the words of Ruskin (p. 155), is the physiological explanation of this optical interest. We may presume that this vibration is caused by a contradiction between the actual appearance and the natural presumption of the eye that the intercolumniations are equal. However this may be, the unpleasant results, to a sensitive eye, of monotony or mechanical regularity in architectural detail, are so well recognized by competent judges, that it is not necessary to insist on any particular optical explanation. Good taste will prefer, without philosophical reflection or close examination, the endless variety of detail which is found in Oriental decoration and in all historic ornament, as superior to the formal and mechanical repetition of detail which is generally found in modern copies of the same ornamental motives. It is probable that a similar vibrant quality may exist in both cases, whether it be that of the variations of an ornamental pattern or the subtle asymmetries of an entire building; but the facts are of greater interest and importance than their physiological explanation.

There is no doubt, for instance, that the trained eye will find additional interest in a series of columns, or arcades, which have slightly irregular intervals; and it is consequently a fact of great significance that the Greek intervals were varied in so many cases by asymmetries of whose definite intention there can be no doubt, because they are systematic as between the fronts and flanks of the temple.

[a] See Dörpfeld, *Olympia: Die Baudenkmäler*, p. 20.

As regards the interesting optical effect of slightly irregular intercolumniations, it may be mentioned that the so-called Maison Carrée at Nîmes, which is the most beautiful surviving example of a Greco-Roman temple, has surprisingly irregular intervals between its engaged columns, as well as the curves in plan previously described (p. 42). Although these irregularities are not detected by the eye, they have a maximum of five inches' variation when tested by measurement.[2] The Maison Carrée will, moreover, be admitted by many who have seen it to be one of the buildings in which the quality inheres which has been specified by Professor Michaelis, and to which his term of "fesselnde Eindruck" may apply.[a]

A similar effect may be observed in the palaces by Palladio at Vicenza, which is probably due to their subtle proportions and to the general use of the entasis in the engaged columns and pilasters. The façade of St. Mark's at Venice is also a notable instance of the fine effects of systematically irregular arcading, as carefully described and figured and wisely and eloquently appreciated by Mr. Ruskin.[b]

We may thus conclude once more—and this time from the facts rehearsed in the last chapter—that the theories of optical correction which have been so widely applied to the refinements of the Greek temples are not only inadequate and generally mistaken in fact, but that they are also generally mistaken in principle. For it is impossible to suppose that a race of builders which tolerated asymmetries of 8 inches' maximum variation in the intercolumniations on a single flank of Temple C at Selinus, and which planned systematic variations of 22 inches for each spacing, as between the intercolumniations on the flanks and fronts of the same temple, could have been capable of devising a system of optical corrections which was intended, in other directions, to make the same class of buildings appear more mathematically regular and more geometrically formal.

It may be objected that a point of view which includes such pronounced irregularities as an average variation of 22 inches for each spacing, as between the intercolumniations of the fronts and flanks of a temple, defeats its own argument by quoting an arrangement which must have been so conspicuous as to be ineffective for its supposed purpose. Some consideration of this possible objection is desirable. It may, however, be immediately met by the reflection that the spacial contraction at the Parthenon angles amounts to 24 inches, and that this variation is overlooked by every

[a] Literally, an effect which "chains" the eye, which compels its interest or attention (*fesseln*, to chain).

[b] *The Stones of Venice*, Vol. II, Chapter V.

observer. If a variation of 24 inches, as between columnar spacings on the same side of the Parthenon, is not obtrusive to the eye, then a variation of 22 inches as between different sides of Temple C must have been equally inconspicuous.

Equal spaces and equal sizes are never seen as equal, unless they are seen at equal distances. This occurs very rarely. It never occurs when one is looking at a church or a temple. If we place a number of equal objects at equal distances in a circle, and then stand in the centre of that circle, the objects and the spaces will be seen as equal, but there is no point of view from which either the spaces or the columns of a symmetrically spaced portico will appear equal to the eye, unless one stands in the interior of a circular portico and at its centre.

The eye is thus uniformly accustomed to seeing equal spaces and equal dimensions as universally unequal. Its estimates or beliefs as to actual equality are based, so to speak, on convention and on average experience. Such estimates are mainly determined by unconscious, or subconscious, comparison of the presumably nearer and more easily estimated or better-known sizes with those which are more distant or less familiar.

As a matter of fact, our estimates of space and dimension are made by optical guessing. The child who cries for the moon is a familiar instance, at least in quotation, of an unreasonable desire for something wholly beyond reach; but the physiology of optics explains that an infant has not the optical experience which enables it to do its optical guessing properly. The moon appears to be as near its reach as anything else in its immediate neighborhood. At a more advanced age we are exposed to a similar error when we see the moon as larger when it is near the horizon. This is because there are more objects near at hand to contrast with it and to show that it is farther away than the most distant objects with which it can be compared, and we then presume it to be consequently larger.[a]

Thus, to return to the Parthenon, the eye which sees the angle intercolumniations as unequal to the others has never, in its whole existence, seen the other intercolumniations of its colonnades as equal. Since inequality is the normal fact of optical appearance, actual inequality is confused with that which is apparent. That the eye is confused in its experiential estimates of supposed size and distance by actual irregularities of size and distance, is undoubtedly true. It is probably this element of confusion which causes an optical vibration.

[a] Compare the remarks of Thiersch, as quoted in Appendix[3], Chapter V (p. 156). His entire explanation of the perspective illusion which is connected with the Greek Doric columnar diminution is of great importance for the physiology of optics in general.

Within the limits of Greek architecture, and from our experience with an existing temple—viz., the Parthenon—we may therefore conclude that 22 inches' variation, as between the spacings on the flanks and the ends of Temple C at Selinus, was a wholly inconspicuous variation.

Many instances might also be quoted from mediæval architecture of the habitual and universal oversight of much larger variations than 22 inches. One must suffice here—viz., that of Sta. Maria Novella at Florence, where the maximum diminution of 13 feet in the pier-spacings in the direction of the choir is universally overlooked because it is insensibly translated by the eye into perspective effect.[3] The name of a Boston architect might be mentioned who confesses to having surveyed this church as having regular spaces. (He had followed the usual system of assuming that one dimension of a given kind would suffice for an accurate survey.) A further incident relating to this church is equally significant. In 1910 I visited Sta. Maria Novella with a friend who had been previously advised of the given variations. As we were standing in the nave and looking toward the third and fourth bays on the north side, this friend undertook to determine which one of these was the larger bay, the difference between them being actually over five feet. He specified the smaller bay, which was farthest away, as being the larger one, nor could he be persuaded of his error until the distances had been measured for his satisfaction. The frequency of such optical mistakes can best be realised by those who have made a special study of this subject.

We may therefore again conclude from these instances that the spacial variations of Temple C at Selinus were inconspicuous. On the other hand, we may again recall the fact that an average spacial variation of only 2–3 cm. (¾ of an inch–1¼ inches) as between the flanks and fronts of a temple was considered important by the architects of the Zeus temple at Olympia (p. 179). It has also been shown that there was a sequence in time and a gradual change of taste as between these extreme limits of purposed variation, one of which is the largest known, and the other the smallest known, of the given class. It has also been shown that these extremes are connected by a series of progressive changes toward the minimum variation.

It may now be recalled that none of the triglyphs of the Parthenon are exactly centred, either as regards the columns or as regards the intercolumnar spaces over whose centres they are presumably arranged. It is true that these variations from true centring are sometimes supposed to have been only incident to the solution of the problem of the angle triglyphs, but it appears probable that they were also independently preferred for their optical interest and variety of effect. That this view may reasonably be held appears from the proven fact that as subtle a variation as 2–3 cm. was definitely planned in the temple of Zeus at Olympia.

Thus, an effect of vibration, or of "life," rather than an appearance of cold and formal regularity, was the essential virtue, and also appears to have been the deliberate purpose, of the Greek architectural art, at least until the last quarter of the fifth century B.C.

WE may conclude this chapter with a consideration of the general causes for the neglect to which the Greek refinements have been hitherto abandoned by modern architectural and critical literature. This neglect is undeniable and has been specifically instanced in preceding pages (pp. 109–114).

It is sufficiently evident that our modern studies of Greek architectural forms and details lack proportion, and that they have been out of perspective as regards the amount of space and interest which have been devoted to them, when we consider how the spirit and method which inspired these forms and details and gave them real life have been neglected. Two or three sentences are supposed to suffice for this subject in most architectural works, and these few sentences, if the books are of recent date, frequently contain erroneous statements and erroneous explanations, which are mainly and essentially due not so much to the carelessness or ignorance of the individual author as to the general modern neglect of the subject.

This neglect may be partly owing to that lack of public interest in any given subject which is not easily within the grasp of public knowledge. This is eminently the case with the Greek refinements, because they are matters which appeal to the eye, but which it is extremely difficult to illustrate to the eye outside of the original buildings. The illustrations of this book are a sufficient indication of the unavoidable deficiencies of book illustration, which are incident to the delicacy of the curves and to the difficulty of reproducing them in small dimensions so that they are sufficiently visible to the eye. As for the variations of spacing and dimension, and the subtle variations from parallels and from perpendiculars, it is wholly impossible to reproduce either the facts or their artistic effect. This can only be realised in face of the original buildings.

As regards the curves, even were it possible to publish them to advantage, negatives have rarely been taken with the purpose of showing them from the best points of view, which must be selected so as to sight on the foreshortened line, or otherwise in parallel perspective, with a straight line drawn under the curve on the negative.[a] Thus, the only publicly exhibited photographic enlargements of Greek curvatures, either in the United States or in Europe, as far as known to me, are those of the Brooklyn Institute Museum. There is only one other series of negatives made to illustrate curvature. This is the one taken of the Athenian ruins by Mr. W. J. Stillman, and this comprises only three negatives which were especially taken to show the Parthenon curvatures.[b] This series has been published in photogravure, but without text. It may hardly be credited that, aside from the Brooklyn Institute Museum series and the Stillman publication, there are only two other extant published half-tones or photogravures of ancient curvature. One of these represents the Ionic temple at Pergamus,[c] and the other shows the concave curve at Cori (Fig. 29, p. 47).

It may thus be presumed that the difficulties of illustrating the Greek curvature, and also the rarity of photographic illustration, may partly explain the neglect which has befallen this important subject. On the other hand, it might reasonably be held that these deficiencies of illustration are only another and additional instance of the neglect in question. One point, however, is clear. Even the highly enlarged photograph which illustrates the curvature must utterly fail to illustrate its effect. It is only in the dimensions of the building and where the curvature is consequently not noticed, or only seen by careful sighting from special points of view, that it is artistically effective. The photograph is a detective, and is valuable for that reason. It emphasises and demonstrates remarkable facts. On the other hand, those small dimensions of the photograph—as, for instance, in the illustrations of this volume—which make it possible for the eye to detect the curvature in one glance, must not be allowed to determine our impressions of this refinement as applied to real architecture.

It is with the wandering and the moving eye, and with dimensions that are measured by hundreds of feet instead of by units of inches, that we have to deal when considering the physiology of vision and the artistic impressions which are determined by it.

Another, and a more important, explanation of the modern neglect of the Greek refinements may lie in the natural ascendancy—natural at least in English-speaking countries—of the theories of Penrose, and of the

[a] Photographs in parallel perspective are taken with the camera facing in a line which strikes the centre of a given wall and which is exactly at right angles to it. The use of a compass is necessary.

[b] See Appendix[2], Chapter I, p. 28.

[c] See Fig. 72, p. 123, and Appendix[9], Chapter IV. The photograph of the curve at Egesta in Vol. I, p. 154, of the Sturgis *History of Architecture* is taken from a Brooklyn Institute Museum print.

rather grotesque distortion which those theories have experienced. The Greek refinements are generally supposed to have been optical corrections of optical illusions. So considered, they must mainly appear only as one phase of a highly developed and supersensitive culture, without any greater interest for the modern world than that which belongs to other phases of Greek history. That corrections of optical illusions are urgently needed in modern architecture may fairly be doubted. If that fact be doubted, it is evident that the subject, when explained on this basis, has no practical interest for modern architectural critics or for modern architects.

On the other hand, if the Greek refinements were temperamental expressions of a dislike for monotony and formalism and temperamental devices of artists who realised the disastrous results of mechanical methods, then and in that case they will undoubtedly appeal to a certain kind of modern temperament, and may even encourage it to more active self-assertion or self-recognition in independent ways.

This point of view leaves wholly on one side the question as to the desirability of repeating the Greek refinements in modern imitations of Greek architectural forms. That the spirit which inspired these Greek departures from formal symmetry may find widely varying forms of outward expression is sufficiently apparent in mediæval art, and this spirit may therefore reasonably appear in still other forms which are neither Greek nor mediæval, and which are, by contrast, wholly modern.

Perhaps the best, or at least the most obvious, explanation of the virtues of an old Greek temple, when compared with the modern copies of what are supposed to be the same forms, may be found in the analogies which are offered by other related arts. The appeal to these analogies has also the advantage that there are more good critics of painting and etching outside of the profession of the painter than there are of buildings outside of the profession of the architect. Thus the student or advocate of the *pointilliste* method of painting may easily realise that this method of painting, which avowedly relies on optical vibration for its effects of color, has obvious analogies with the taste which asserts the charm of optical vibration for lines, spaces, and dimensions. The admirer of Piranesi (who was an architect as well as an engraver) will easily admit that the taste which prefers a Piranesi etching of a given ruin to an architectural draughtsman's elevation of the same ruin, may also apply to buildings as well as to the drawings which are made of them. The methods of painters as far apart as Whistler, Monet, Raffaelli, and Monticelli, all have something in common which distinguishes them from a typical British painter of the mid-Victorian period. That something is akin to the vibratory effect of the Poseidon temple or of the Maison Carrée.

It may be added that the general issue at stake between artists like Whistler or the so-called Impressionist painters and the theoretically (but not actually) more literal art which they have opposed and largely supplanted, is an issue between men who see with their eyes and men who see with their brains. It was a pregnant discovery of Hauck's that the curves actually found in natural vision and in actual perspective were more easily seen by artists and by women, and that they were less easily seen by mathematicians and by men of science (p. 56). Not less interesting was his observation of a progressive improvement in his own vision after he had begun to devote attention to the subject. In the attitude of various individuals toward architectural design the same temperamental differences and distinctions exist, and may largely explain the scepticism of Professor Durm and others on the general subject of so-called refinements, or of purposed variations from mechanical symmetry, in architecture.

This scepticism may be, to some extent, the expression of a temperamental intellectual indifference, and consequently of optical indifference, to a point of view which has undeniably found distinguished sympathisers of another temperament in our own period, and which undeniably found an active and practical expression which is almost incomprehensible to average modern thought, not only in the architectural works of the Greeks, but also in those of the mediæval builders. On this last subject I hope to make some later contributions to these studies in other volumes of this series.

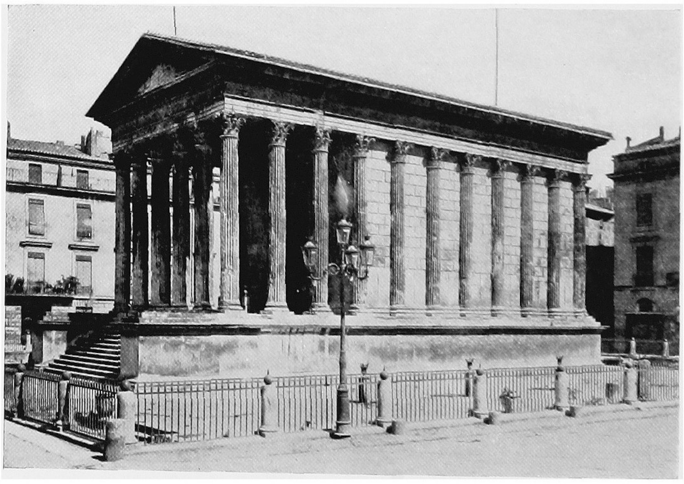


Fig. 118. The Maison Carrée at Nîmes.

# APPENDIX. CHAPTER VII

[1] "Die Verhältnisse der einzelnen Bauglieder in Zahlen zu formuliren ist öfters versucht worden, z. B. von Penrose, doch sind die gefundenen Proportionen meistens so complicirt und bei den verschiedenen verglichenen Bautheilen so verschiedenartig, dass es schwer fällt darin eine Absicht zu erkennen. Vielleicht berührt der fesselnde Eindruck der allgemeinen Proportionen des Gebäudes eben darauf, dass keine commensurablen Zahlen dabei zu Grunde liegen, und damit würde diese Erscheinung in die gleiche Reihe mit einer ganzen Anzahl weiterer Beobachtungen treten." *Der Parthenon,* pp. 17, 18.

[2] These measurements, which were taken by the writer in 1891, were first published in the *American Journal of Archæology,* Vol. X, No. 1 (1895), in an article entitled "A Discovery of Horizontal Curves in the Roman Temple called Maison Carrée at Nîmes." The articles of similar title which appeared about the same time in the *Architectural Record* and in the *Smithsonian Reports* did not include these measurements.

The maximum variations of intercolumnar spacing are as follows: On the east flank, 5 inches; on the west flank, 3 inches; at the north (façade) end, 3 inches; at the south end, 3¼ inches. The measurements in detail follow here, in feet and inches:

West flank, measures from south to north: 4′ 2″; 4′ 3″; 4′ 3½″; 4′ 3½″; 4′ 4¼″; 4′ 5″; 4′ 3½″; 4′ 3″; 4′ 3″; 4′ 4½″.

East flank, measures from south to north: 4′ 6″; 4′ 6″; 4′ 3″; 4′ 4¾″; 4′ 3″; 4′ 5½″; 4′ 1½″; 4′ 1″; 4′ 3½″; 4′ 4″.

North (façade) end, measures from east to west: 4′ 1½″; 4′ 0½″; 4′ 3″; 4′ 1″; 4′ 0½″.

South end, measures from east to west: 4′ 0″; 4′ 1″; 4′ 3¼″; 4′ 1″; 4′ 3″.

The maximum variation of columnar intervals in the Parthenon, aside from the angles, is 1¾ inches (p. 190). Thus the maximum variation in the above measures on the east flank is about three times as great as that of the Parthenon; but as the Parthenon intervals are twice as wide as those of the Maison Carrée, the relation of variation to the given space is about six times greater in the Maison Carrée.

[3] The words "perspective effect" do not necessarily imply an apparent increase of dimension. They may indicate any effect which is attributed by the eye to a variation of distance. An effect of greater size is undoubtedly the result in looking toward the choir and sanctuary, which in mediæval churches was, and in Catholic churches still is, the most important part of the church, the part which it was important to emphasise, and the one toward which the eyes of a worshipping congregation were di-

rected. The measurements (in feet and decimals) of the bays in Sta. Maria Novella are as follows, in order from the entrance to the transepts:

37.60 : 38.70 : 40.80 : 35.35 : 27.80 : 27.80

The purpose of making the third bay the largest was probably based on the presumption that the entering spectator is not likely to turn squarely to right or left, and that a diagonal or slanting view, after entrance, is most likely to strike the third bay and to consider it as the standard of a series of equal dimensions. If the four bays, beginning with the third, inclusive, are estimated by the eye as being each of the same size as the third (40.80)—and this is beyond debate the estimate of every eye looking toward the choir from points nearer the entrance than the third bay—then the church appears to be about 31 feet longer than it actually is ($40.80 \times 4 = 163.20$ : $40.80 + 35.35 + 27.80 + 27.80 = 131.75$). There is another optical illusion in this church, which is much less easily detected, and which will be mentioned in a later volume.

Fig. 119. Fragments of a Doric Capital, Temple of Zeus, Girgenti.
Belonging to one of the exterior engaged columns, which were 55 feet high, including capitals, with a diameter of 14¾ feet. Brooklyn Institute Museum Series of 1895.

# INDICES

# INDEX OF AUTHORITIES

With page references to the subject-matter of mentions and quotations and to the biographical notes relating to the authors.



[a] Various experts have collaborated in the production of this work. Dr. Bohn is the author of the volume entitled *Die Theaterterrasse.*

[a] References to publications on mediæval architectural curves will be found in foot-note, p. 117. The following is a partial list of publications by the author on mediæval asymmetries and refinements: *Catalogue of Photographs and Surveys of Architectural Refinements in Mediæval Buildings; lent by the Brooklyn Institute Museum;* published by the Edinburgh Architectural Association, Edinburgh, 1905. *Architectural Record,* New York: Vol. VI, Nos. 1, 2, 3, 4 (1896–7); Vol. VII, Nos. 1, 2, 3 (1898); Vol. XVI, Nos. 2, 5, 6 (1904); Vol. XVII, No. 1 (1905). *American Architect,* New York: August 4, September 8, October 27, December 1, 1909; January 26, March 16, September 28, November 23, 1910; January 25, 1911. *Bulletin of the Brooklyn Institute of Arts and Sciences,* Brooklyn, N. Y., Vol. VI (1911), Nos. 1, 2, 3, 4, 6, 7, 9, 14, 15, 18. *Memoirs of Art and Archæology;* published by the Brooklyn Institute Museum: Vol. I, No. 1, *A Renaissance Leaning Façade at Genoa* (1902); Vol. I, No. 2, *The Architectural Refinements of St. Mark's at Venice* (1902); Vol. I, No. 4, *Vertical Curves and other Architectural Refinements in the Gothic Cathedrals and Churches of Northern France* (1904); Vol. I, No. 3, was announced as a monograph on the Pisa Cathedral but not published; it is replaced by the Bulletins of the Brooklyn Institute as above quoted. *Journal of the Archæological Institute of America:* Vol. VI, No. 2, new series (1902); Vol. XIV, No. 4; Vol. XV, No. 3. *Revue de l'Art Chrétien* for July, 1908, Paris, Champion. *The Architectural Review,* London: September and October, 1906. *Journal of the Royal Institute of British Architects,* London: Third series, Vol. XV, No. 1 (1907); third series, Vol. XVI, No. 19 (1909). *Scribner's Monthly,* New York: August, 1874

The most complete review of the author's mediæval research is that written by Dr. Prof. Antonio Taramelli, Director of the Museum of Cagliari. This appeared in *L'Arte,* Vol. III (1900), pp. 137–140. Rome, Ulrico Hoepli e Danesi

# INDEX OF SUBJECT-MATTER[a]



[a] Temples are indexed under their respective localities.

# INDEX OF ILLUSTRATIONS

Arranged in alphabetic order by localities, the temples under each locality being also in alphabetic order. The numbers refer to pages.[a]



[a] Illustrations relating to optical illusions or to architectural definitions are indexed after localities.

Fig. 120. Temple of Concord, Girgenti.

καὶ μὴν ἀριθμὸν
ἔξοχον σοφισ-
-μάτων
ἐξηῦρον αὐτοῖς
γραμμάτων τε συν-
-θέσεις
μνήμην θ' ἁπάντων
μουσομήτορ' ἐρ-
-γάτιν

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