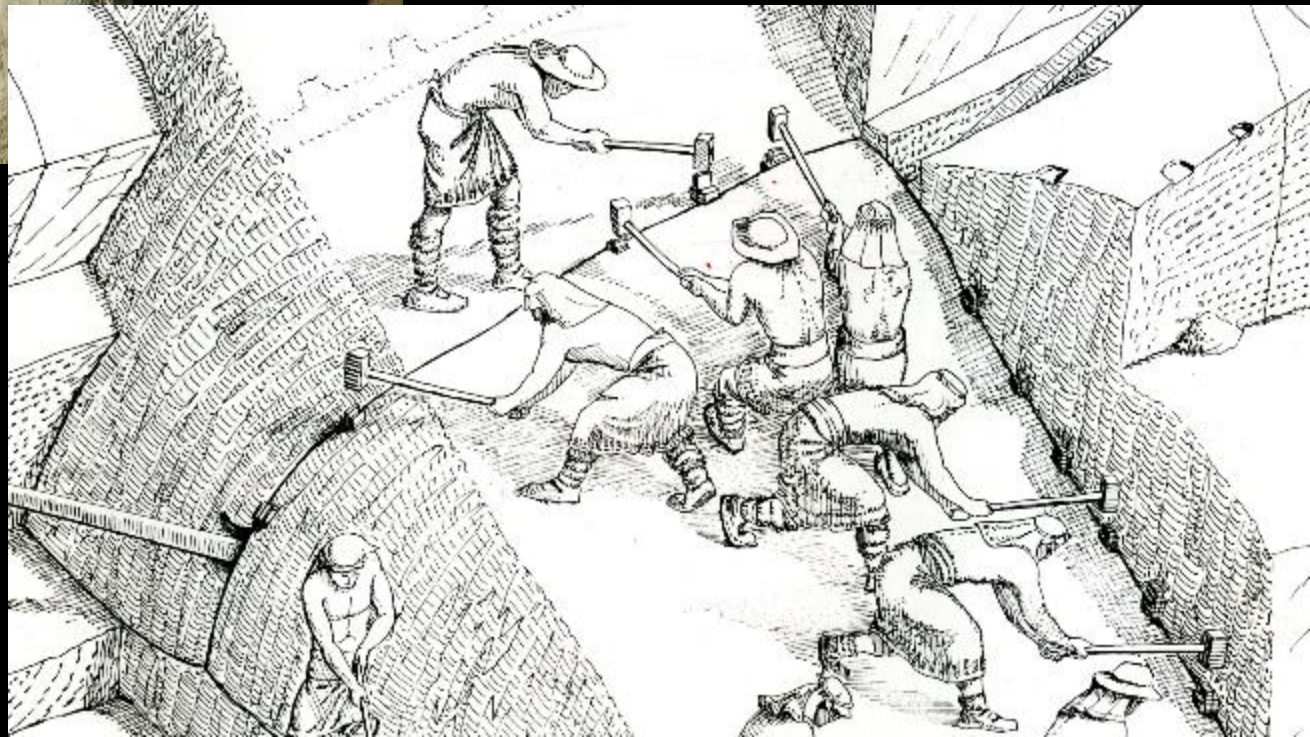
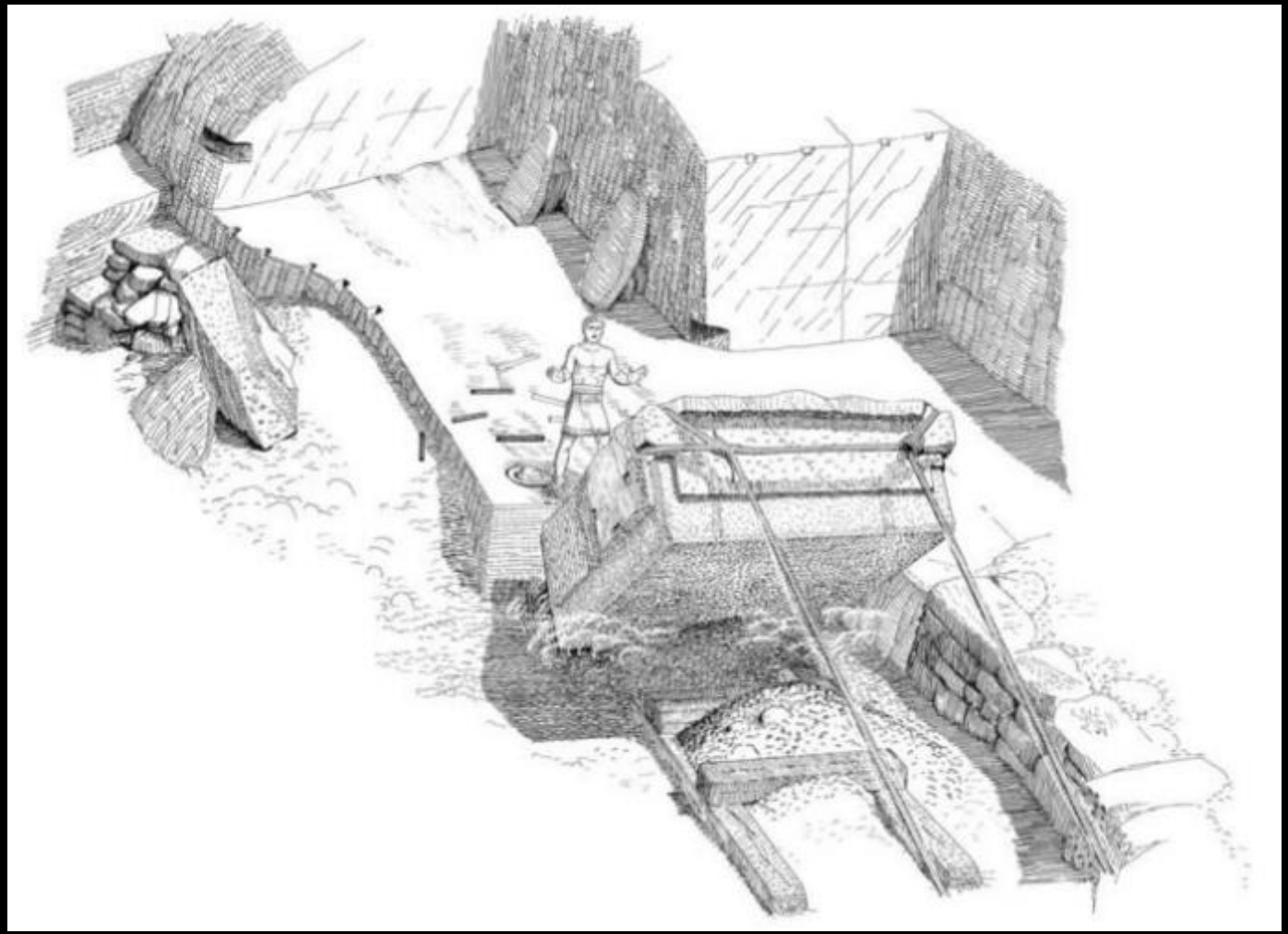
Stone: From Technique to Technology

Part 3: The Impact of Geometry and Mathematics
Renaissance, Enlightenment to Modern

Two of the major impediments to building with stone are:
Quarrying
Carving

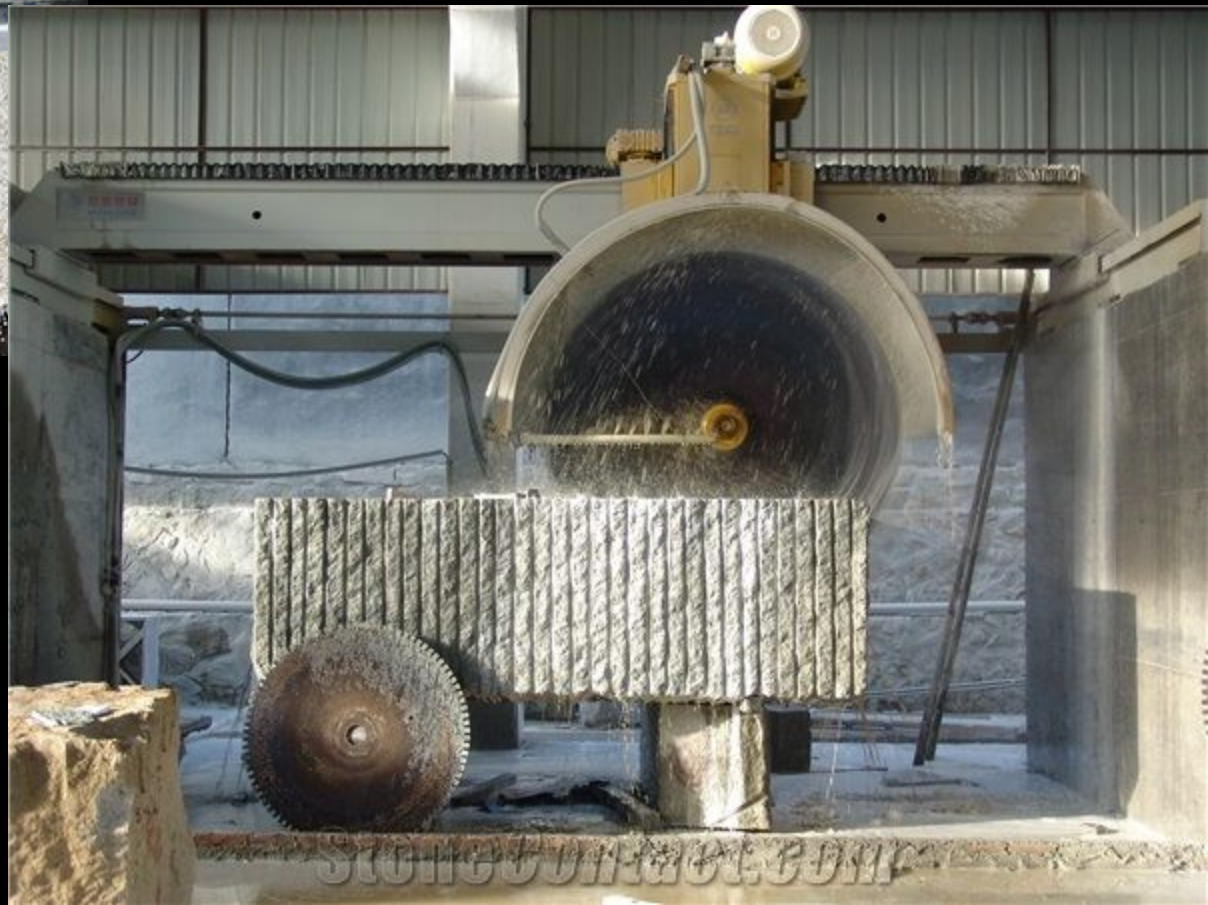


Not all stone that is naturally occurring is
great to build with and quarrying is difficult



Tools needed to be made from iron which was not available in the early ages
Carving improved when the tools could be made more precisely

The ability to craft finer tools led to more fine detail in the building decorations and sculptures



Industrial diamonds are embedded into the tips of the 21st century saws that are used to cut stone.

5 axis CNC cutting machines can take information from a 3D model and cut the stone to a precise shape

How did inventions in mathematics impact the way that people "see" and represent in their "art"

How did that come to change the way we measure and are able to be more precise in our building methods.

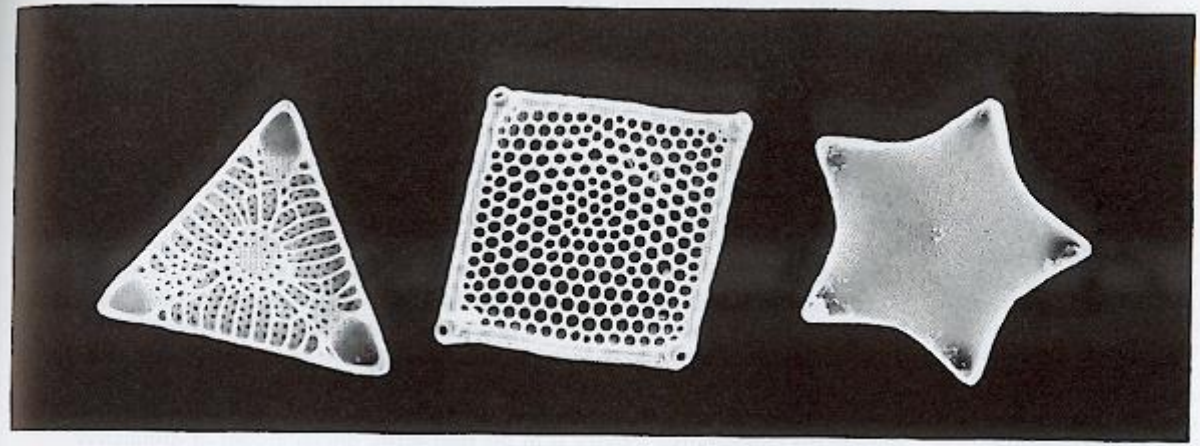

Egyptian art:
Flat, no perspective

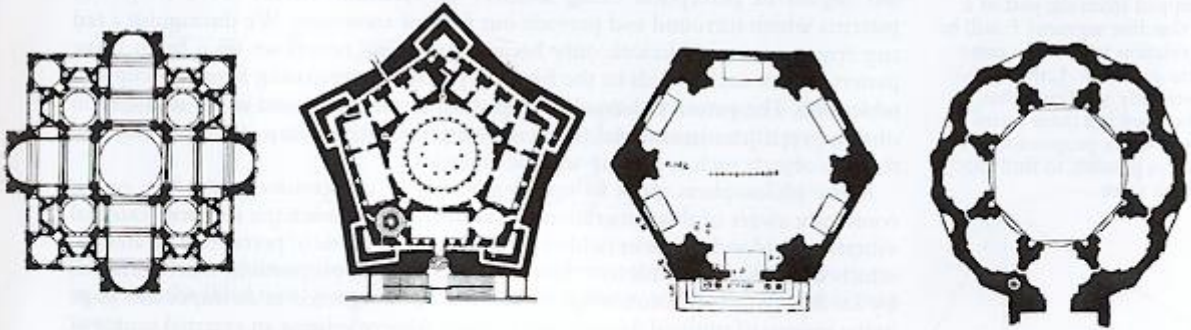
Medieval representation:
No ability to create
"accurate" perspective

Robert Lawlor

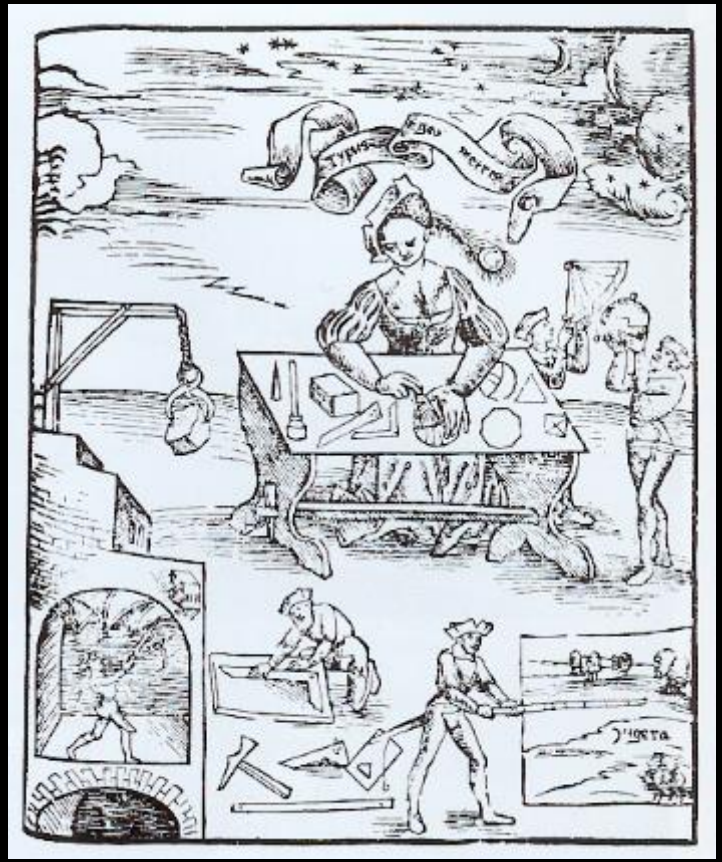
Philosophy and practice

sacred geometry





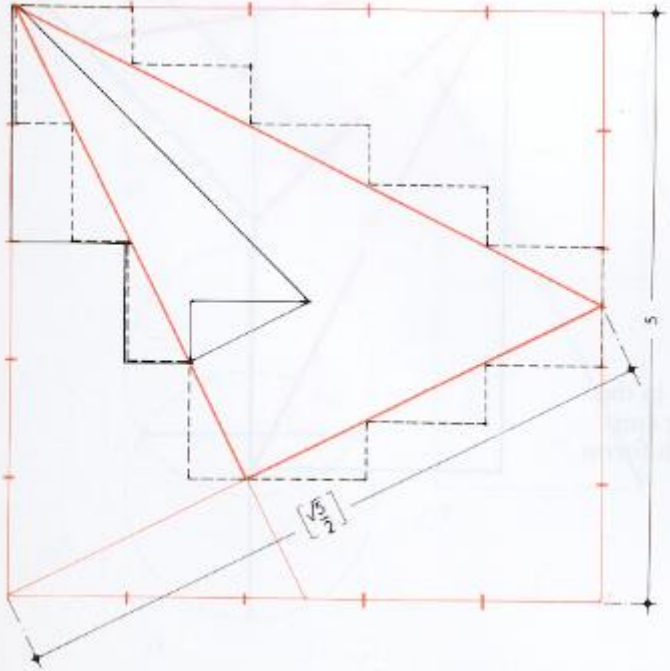
The numbers which emerge from the 3, 4, 5 'Pythagorean' triangle provide beautiful symmetries for natural forms. This series begins with a natural expression of the equilateral triangle and concludes with a series of symmetries used as the inspiration for ground plans in Renaissance architecture.

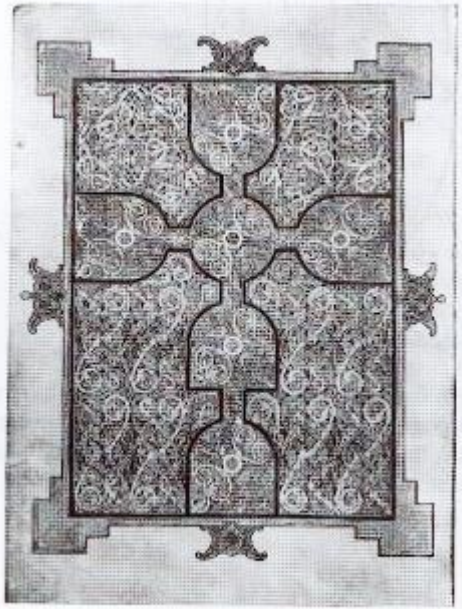



PVS A
RITH
ME
TICAE

Pythagoras (590-470 BCE)

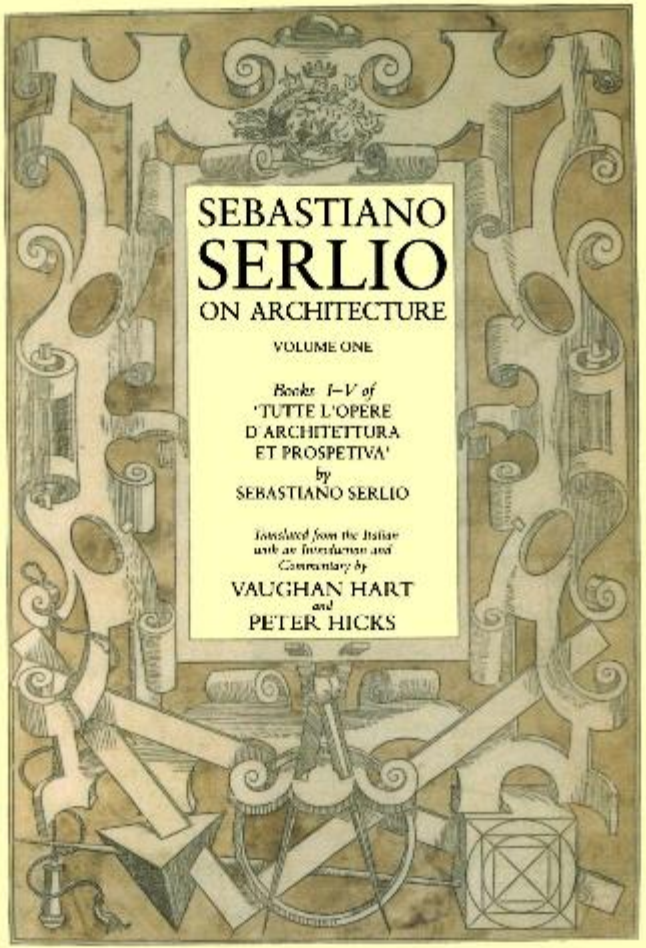
In antiquity, Pythagoras was credited with many mathematical and scientific discoveries, including the Pythagorean theorem, Pythagorean tuning, the five regular solids, the Theory of Proportions, the sphericity of the Earth, and the identity of the morning and evening stars as the planet Venus.



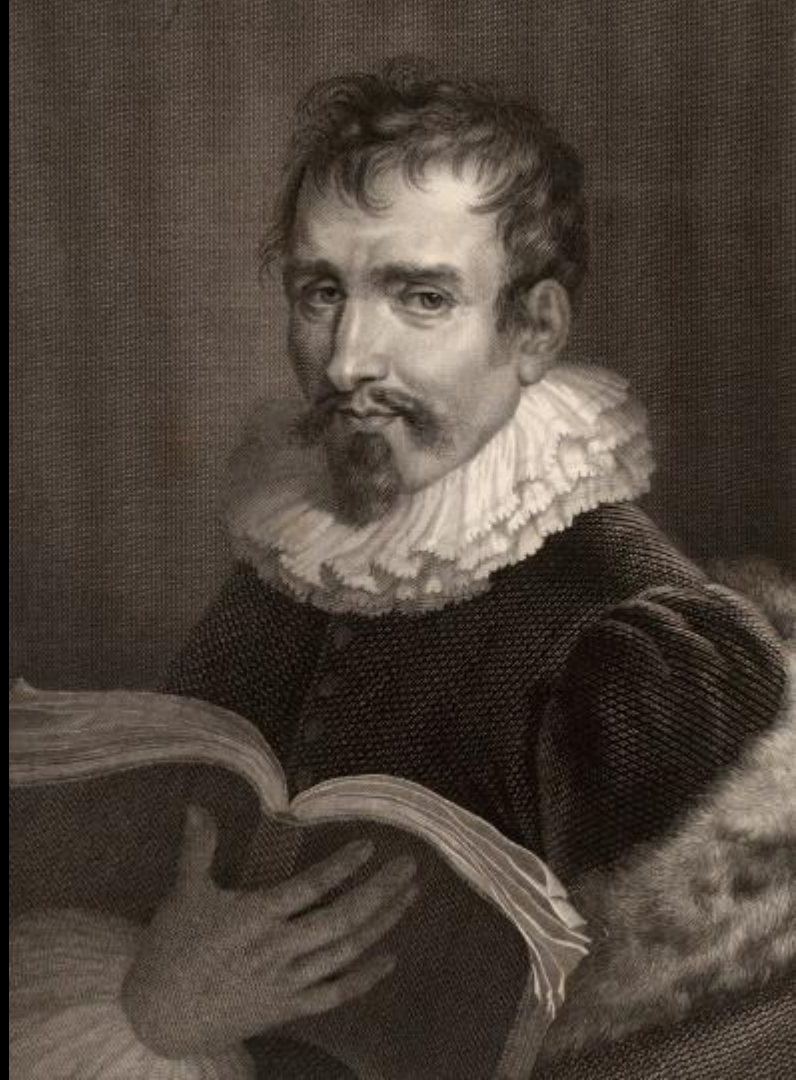


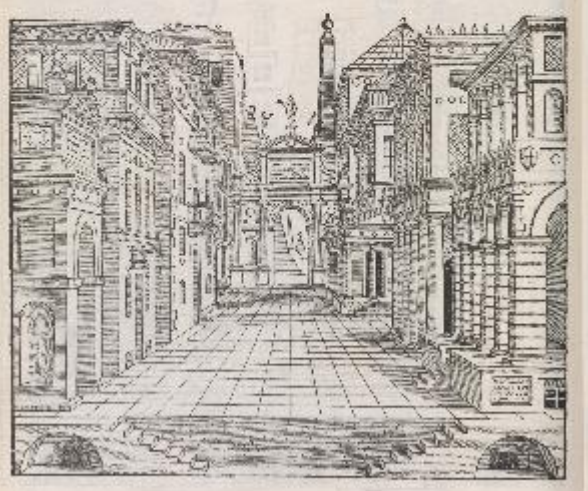
Design of a page from the Lindisfarne Gospels (*c.* AD 700) with proportions based on the 3, 4, 5 triangle.

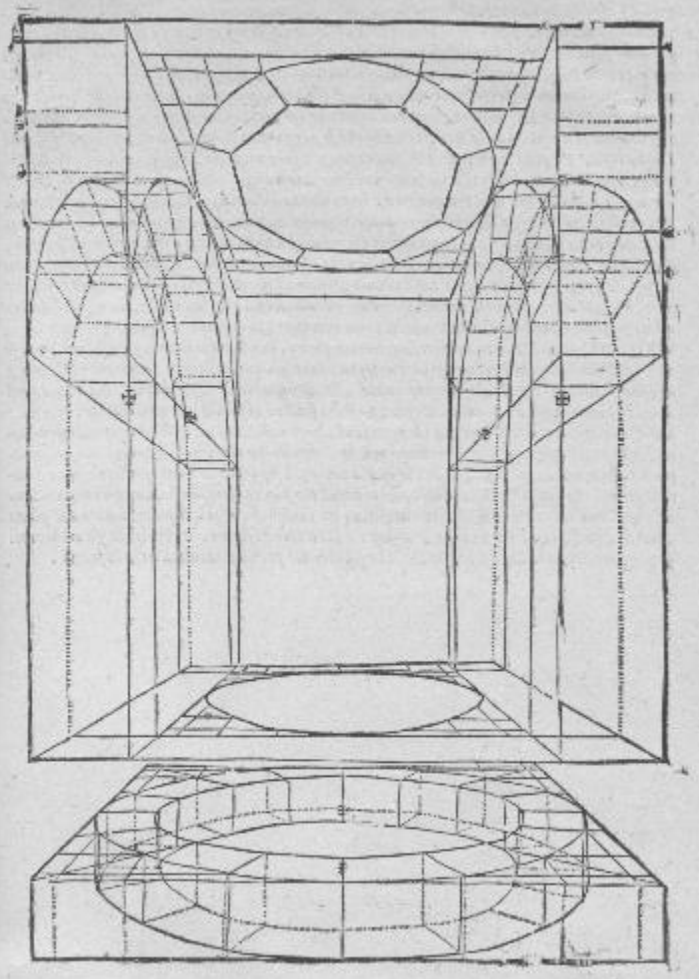
The Renaissance
(Humanism)
1400 to 1550 CE



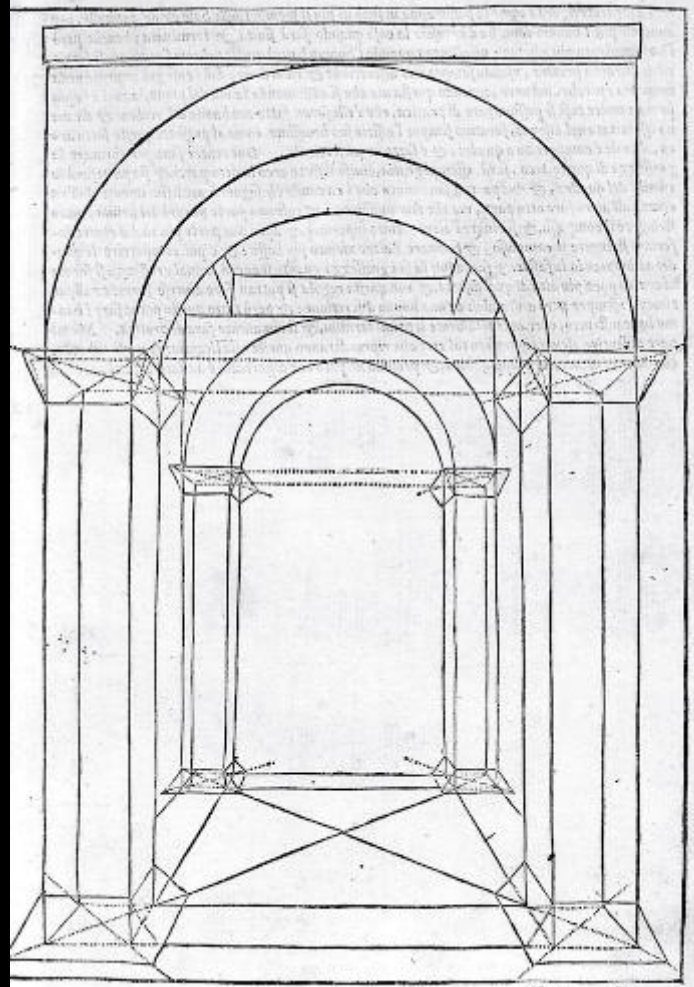
Sebastiano Serlio
Italian Architect
1475-1554

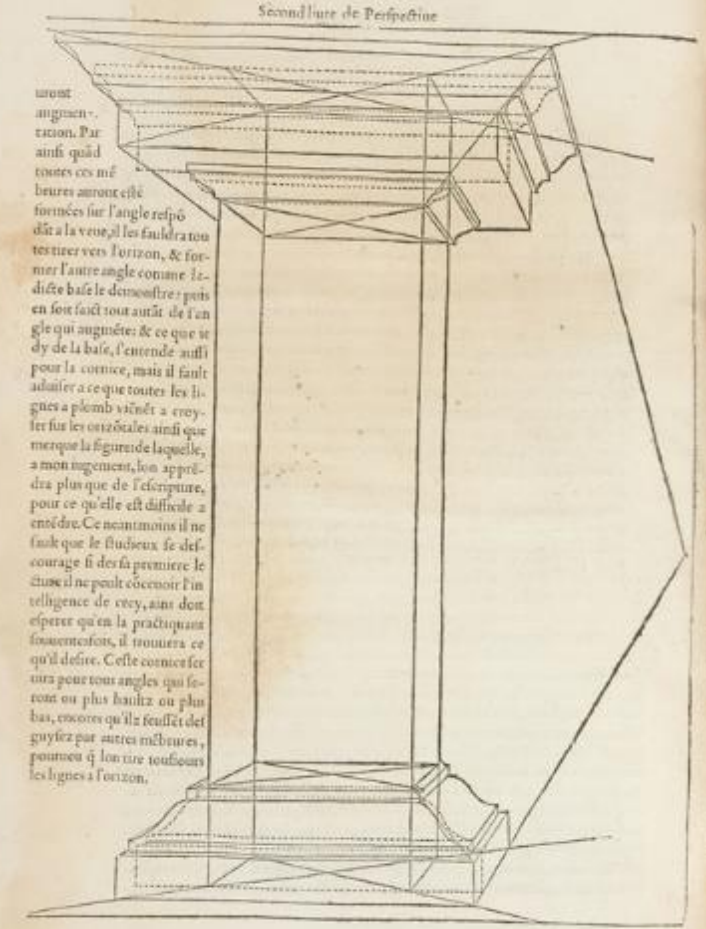




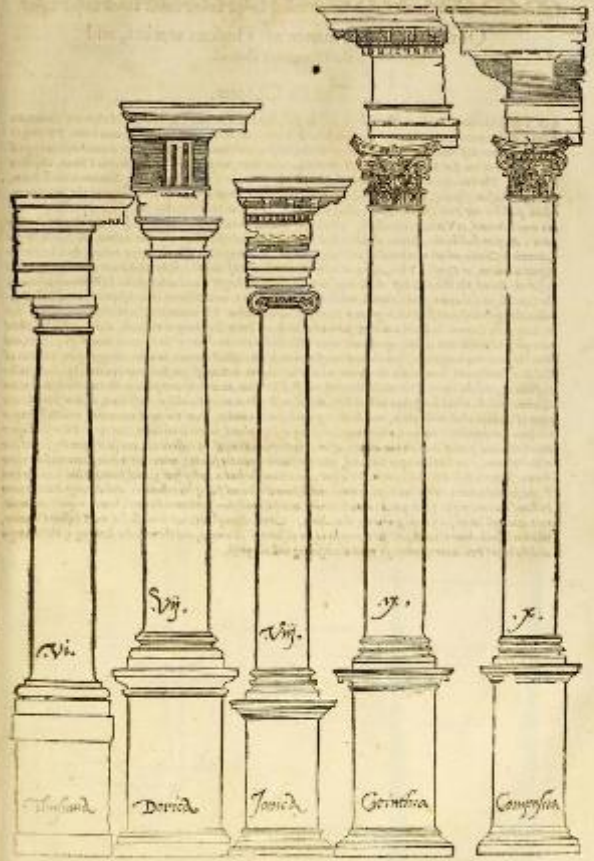


Circa

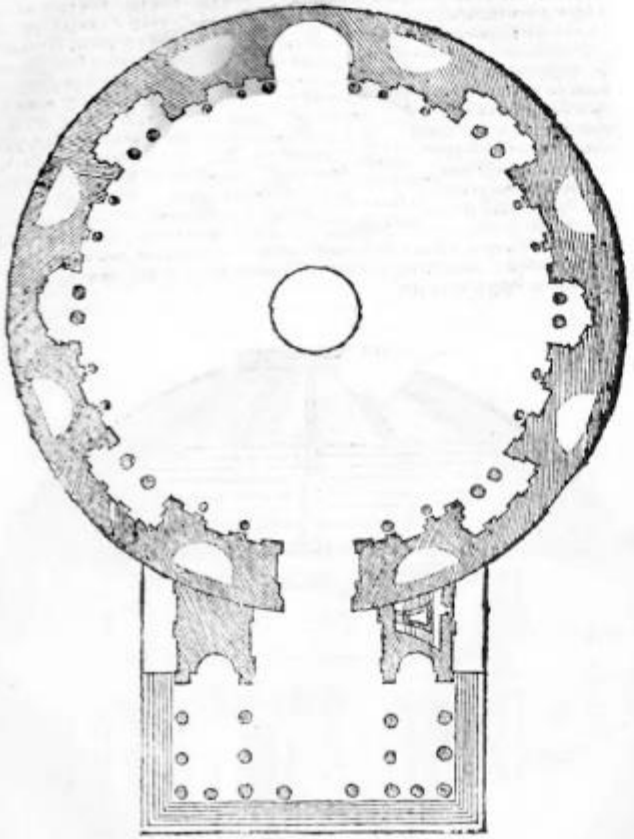




uront augmentation. Par ainsi quād toutes ces mēbreures auront esté formées sur l'angle respōdāt a la veue, il les faudra tourner vers l'orizon, & former l'autre angle comme ledicte base le demonstre: puis en sont faict tout autāt de l'angle qui augmēte: & ce que se dy de la base, l'entende aussi pour la cornice, mais il fault aduiser a ce que toutes les lignes a plomb viēnēt a creyser sus les orizōtales ainsi que mesme la figure de laquelle, a mon iugement, lon apprēdra plus que de l'escripture, pour ce qu'elle est difficile a entēdre. Ce neantmoins il ne fault que le studieux se descourage si des sa premiere lecture il ne peult cōcepuoir l'intelligence de cecy, ains doit esperer qu'en la practiquant souuentesfois, il trouuera ce qu'il desire. Ceste cornice seruira pour tous angles qui seront ou plus hault ou plus bas, encores qu'ilz feussēt deguyez par autres mēbreures, pourueu q̄ lon tire touiours les lignes a l'orizon.



Pianta del Pantheon.

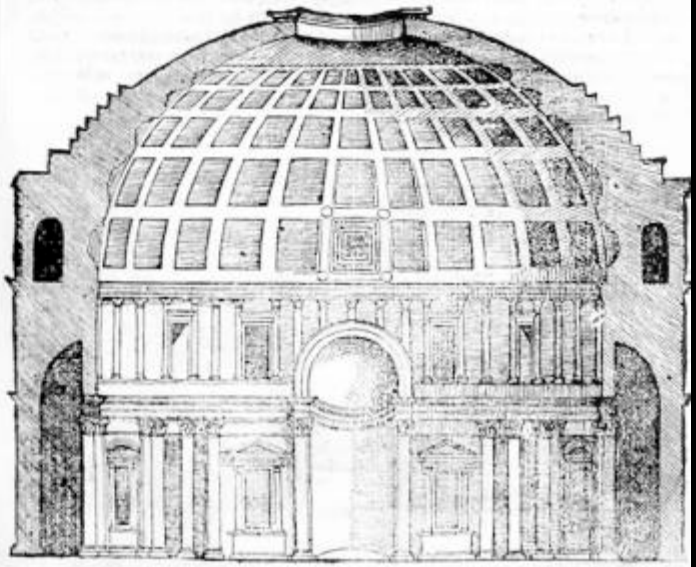


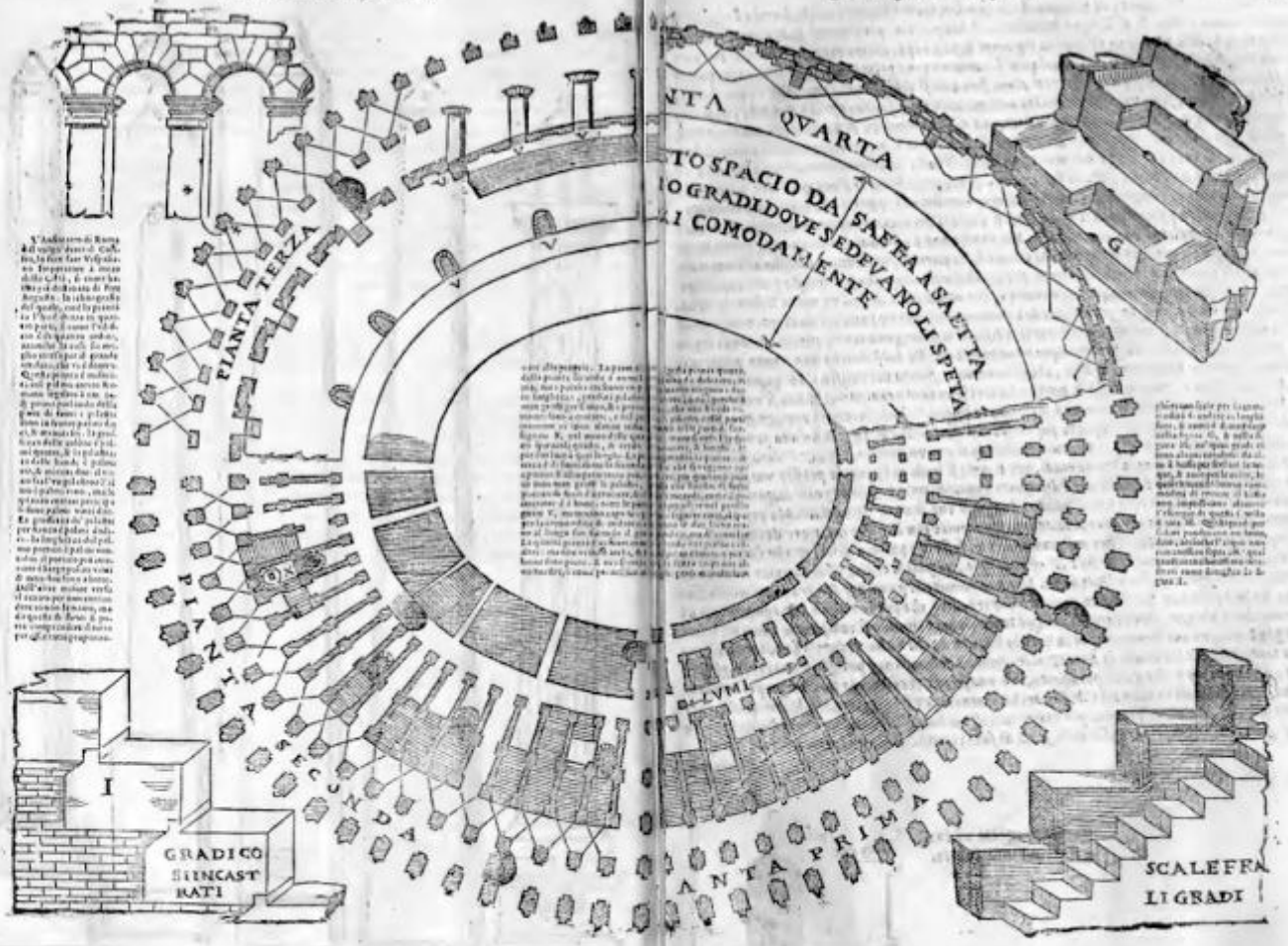
La parte di dentro del Tempio.

Questa seguente figura dimostra la parte di dentro del Pantheon, la qual forma è tolta dalla rotondità perfetta: percioche tanto è la sua larghezza da muro a muro, quanto è dal pauimento fin sotto l'apertura, che come ho detto più adietro, è per diametro palmi cxciii. & è tanto dal pauimento alla sommità dell'vltima cornice, quanto da quella alla sommità della volta done è l'apertura. Le riquadrature che sono in essa volta, o vogliam dire Cielo, sono tutte nel modo ch'è nel di mezo, & è opinione che fossero ornati di lame di argento laurato, per alcune vestigie, che ancora si vegono: perche se di bronzo fossero stati tali ornamenti, per le ragioni dette più adietro, sariano stati spogliati gli altri bronzi, che ancor sono nel portico.

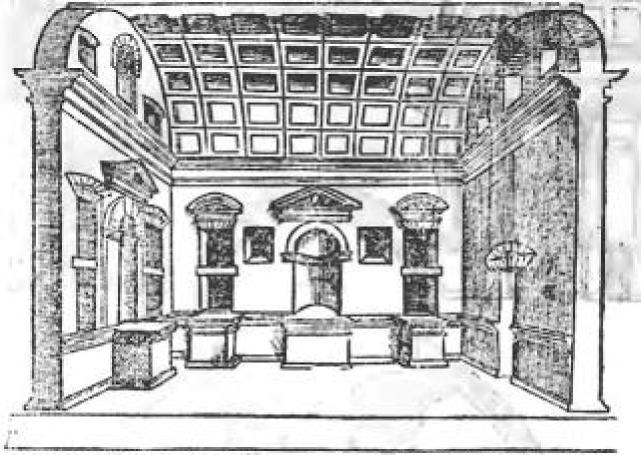
Non si marauigli alcuno se in queste cose che accennano alla prospettiua, non vi si vede scorcio alcuno, né grossezze, né piano: percioche hò voluto leuarle dalla pianta dimostrando solamente le altezze in misura. ciocche per lo scorciare le misure non si perdino per causa de iscorcimi ben poi nel libro di prospettiua dimostrerò le cose ne' suoi veri scorci in diuersi modi, in superficie & in corpi, in varie forme, & gran copia di varij casamenti pertinenti a tal arte: ma nel dimostrare queste antichità per seruare le misure non vserò tal arte. Dalla cornice in giù non dirò hora le misure delle cose, perche più auanti a parte per parte dimostrerò le figure, & ne darò le misure minutamente.

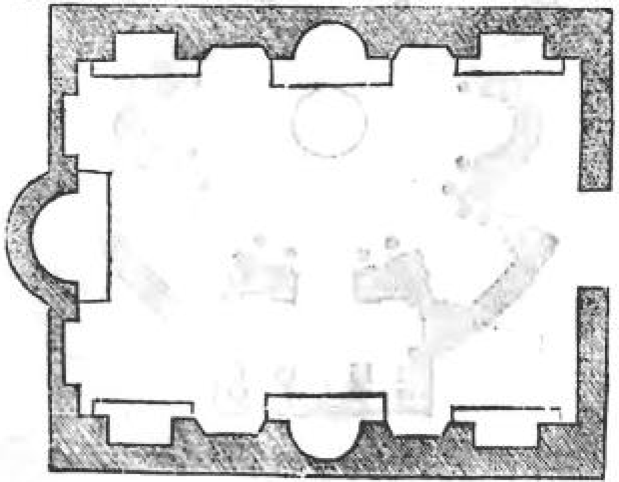
La capella di mezo ancora ch'ella sia benissimo accompagnata con tutta l'altra opera; nondimeno è opinione di molti che non sia antica: perche l'arco di essa viene a ropere le cinque colonne, cosa che non vsarono li buoni antichi. ma che al tempio de' Christiani ella sia stata cresciuta, come più conviene a' Tempij de Christiani di hauer vn'altar principale: & maggior de gli altri.



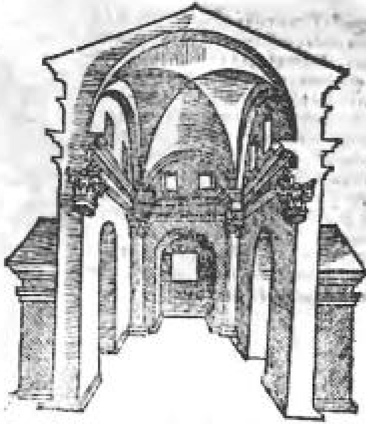

NTA QVARTA
TO SPACIO DA SAETTA A SAETTA
IO GRADI DOVE SEDEVANO LI SPETA
I COMODAMENTE
PIANTA TERZA
PIANTA SECONDA
PIANTA PRIMA
LVIII
I
GRADICO
SIINCAST
RATI
SCALEFFA
LI GRADI

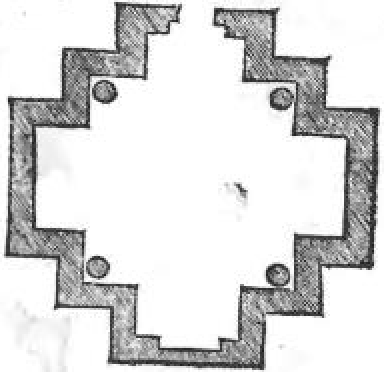
Il Tempio qui sotto dimostrato è fuori di Roma molto rovinato, & la maggior parte di pietra cotta, & non è molto grande, nè si comprende d'onde havesse luce se non dalla porta, & dalle finestre alte per testa sopra le cornici, tutti gli altri fori eran luoghi da statue ò dadali, ò cose simili. La misura di questo Tempio si perdette per il viaggio, & però io non la pongo altrimenti; ma l'Architetto si potrà valer della inventione: ma hò ben a memoria che'l Tempio di dentro era un quadro e mezzo, così nella pianta, come nell'altezza.



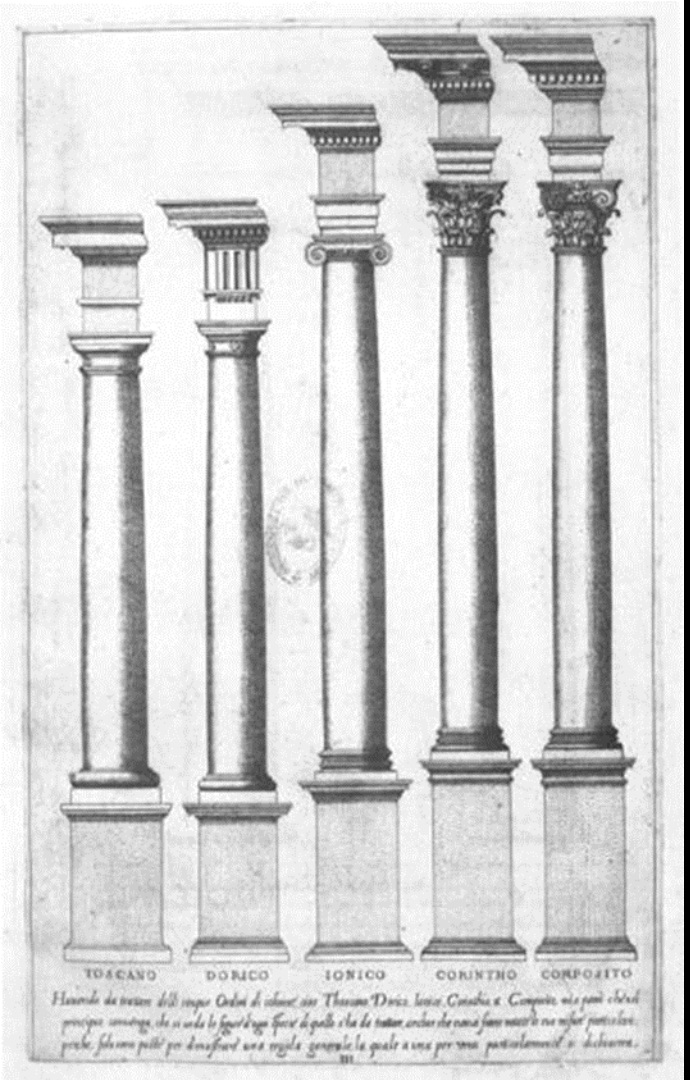


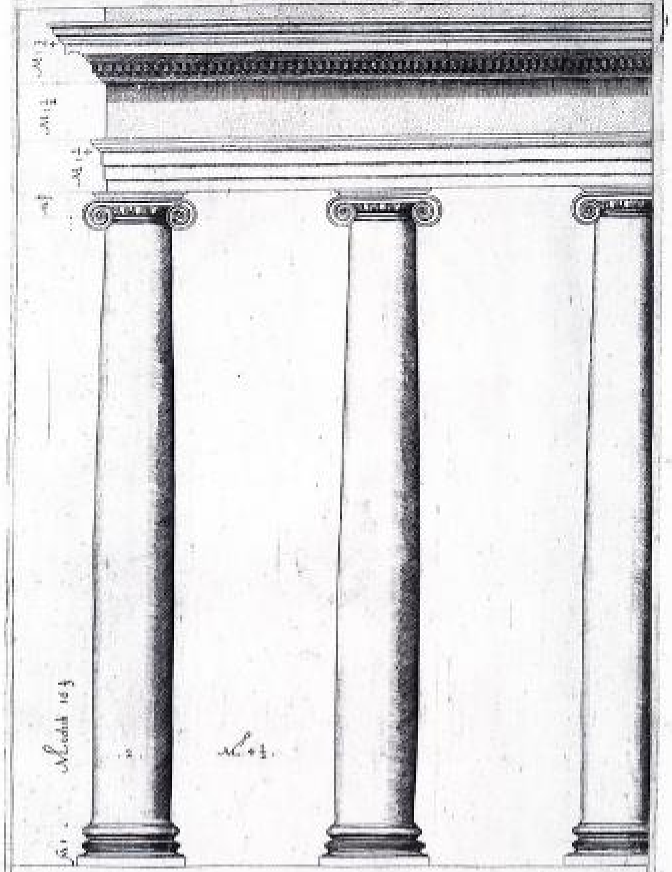
Il presente tempio è fuori di Roma, parte di pietra cotta, & parte di marmo, ilquale è rovinato assai, & si giudica che fosse un sepolcro, & è di forma quadrata perfetta per ogni verso: da muro a muro è circa palmi trenta. La grossezza del muro è palmi due & mezo. La larghezza delle capelle è palmi dieci. La porta è larga palmi cinque. L'altezza delle colonne con le base, & i capitelli è palmi ventidue & mezo. La grossezza d'esse è poco più di due palmi. L'architraue, il fregio, & la cornice è alta da palmi quattro, dalla cornice alla sommità della volta è da palmi undeci. L'altezza de gli archi delle capelle è palmi venti.



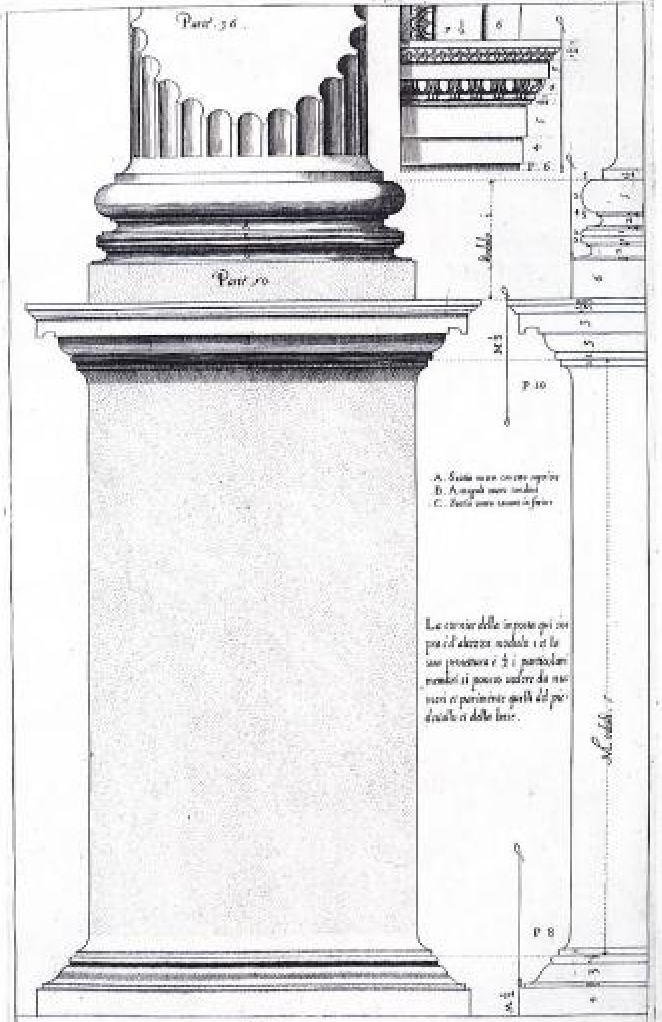


Andrea Palladio
Italian Renaissance
Architect
1508 - 1580

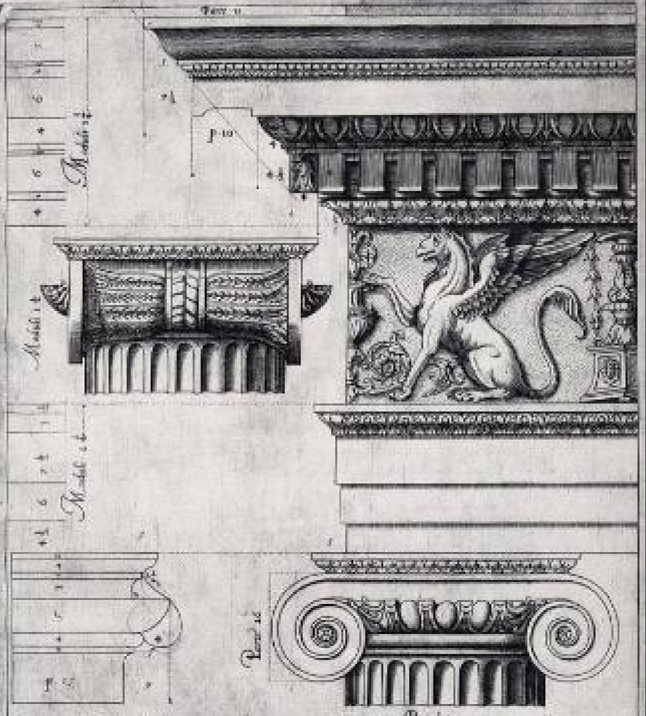


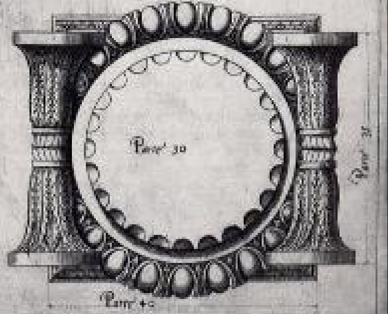


Havendosi à fare l'ordine Ionico senza il piedestallo tutta l'altezza si ha da partire in parti 22 ½ et d'una di queste farne il modulo, il quale va diviso in parti 18, et questo aviene che per essere ordine più gentile del Toscano et del Dorico ricerca più minute divisioni. la sua colonna deve essere 18 moduli con la base et capitello, lo architrave modulo 1 ¼ il fregio modulo 1 ½ la cornice modulo 1 ¾ tutti insieme architrave fregio et cornice sono moduli 4 ½ che è la quarta parte dell'altezza della colonna

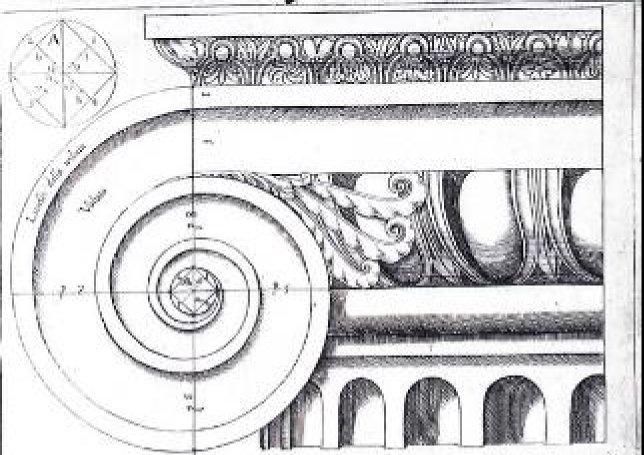


La cornice delle imposte qui sopra è d'altezza modulo 1 et la sua proiettura è ⅔ i particolari membri si possono vedere da numeri et parimente quelli del piedestallo et della base.





Il modo di fare il capitello Ionico avvenga che nella presente carta sia disegnato con la pianta et profilo à più chiara intelligentia si deve tirar due linee a perpendicolo discosto moduli l'una dall'altra le quali passano per il centro degli occhi delle volute et sono chiamate Catheti. Tiene la voluta di altezza 16 parti di modulo 8 sopra l'occhio il quale è di due parti et le sette restanti di sotto. Il modo col quale si fanno queste volute è disegnato nella seguente carta et col tempo brevemente notato per quanto comporta lo spatio il modo con che si procede.



Tirato il Catheto di questa prima voluta et un'altra linea in squadra che passi per il centro dell'occhio si divide il detto occhio nel modo segnato di sopra nella figura A. et si comincia poi al primo punto segnato 1. et si gira col compasso una quarta di circolo dipoi al punto segnato 2. si gira l'altra quarta et così procedendo si fa i tre giri compitamente. Per far poi la grossezza del listello il quale è la quarta parte della larghezza che lascia di sopra il primo giro così s'ha da partire ciascuna di quelle parti che sono servite per centri in 4. et girando poi altre 12. quarte di circolo con quelli centri sarà fornita.

Volendo fare la voluta nel modo qui sotto disegnato tirisi la linea detta Catheto la quale sarà alta parti 16 cioè un modulo 9 per si devono mettere di sopra del centro et parti 7 di sotto et in detto centro fare la divisione della circonferenza in parti 8 come si è disegnato D. poi devesi fare il triangolo B.C.D. che la linea B.C. sia parti 9 cioè un modulo et la linea C.D. sia parti 7 et perchè si può vedere, et conoscere per il disegno fatto per numeri parmi che basti a saperla formare. Dipoi devesi rapportare su le linee che ne dividono la circonferentia della voluta le parti della linea B.C. come si vede per numeri segnati. Et nel girare poi da un ponto all'altro si trova il centro mettendo il piede fermo del compasso nel punto segnato 1. et allargandolo fino al centro dell'occhio della voluta si tira un poco di circonferenza dentro il detto occhio poi senza mover il compasso si metti il piede fermo sopra il punto segnato 2. et dove va ad incontrare su quella poca di circonferenza segnata quivi sarà il centro della circonferenza da 1. à 2. poi si metta il piede fermo del compasso nel punto 2. et si stringe fino al centro dell'occhio della voluta et si tira parimente un poco di circonferenza poi senza movere il compasso si metti il piede fermo nel punto 3. et girando dove s'incontra in quella poca parte di circonferenza quivi sarà l'altro centro che tirerà la parte di voluta da 2. à 3. et così si procede di mano in mano.

Korinthische Ordnung

Jonische Ordnung

Korinthisch

Römisch-Korinthisch

Kapitäl u. Basis vom Monument des Lysikrates zu Athen.

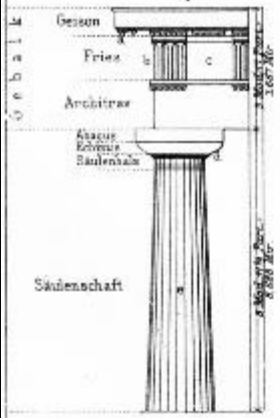
Kapitäl u. Basis vom Tempel der Athene zu Athen.

Kapitäl vom Tempel der Athene zu Priene

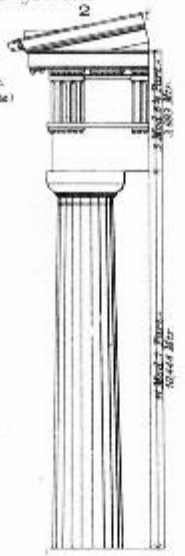
Kapitäl vom Tempel am Ilissos zu Athen.

Zu 1. 2. 3.

a Mutuli (Dielenköpfe)
b Triglyphen (Dreyschlitze)
c Metopen
d Riemchen
e Kannelirungen
f Sima (Rinnleiste)

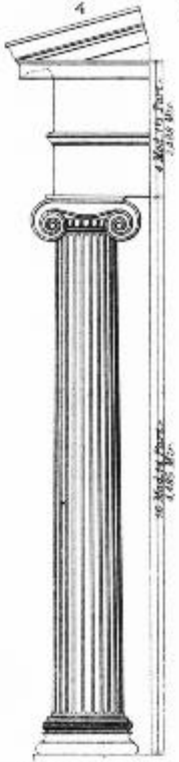


Vom Tempel zu Pästum

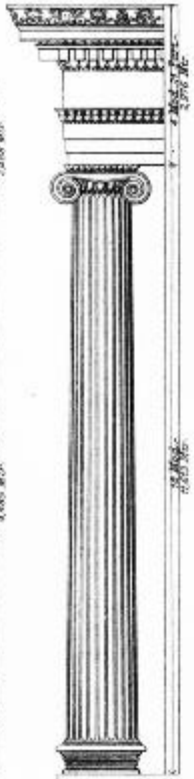


Vom Parthenon zu Athen

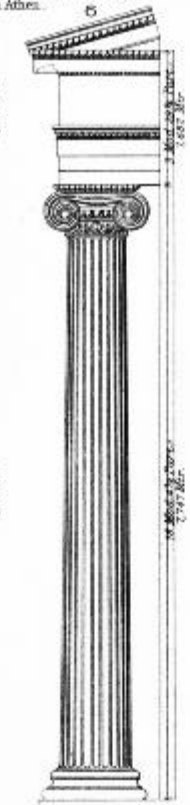
Vom Tempel des Memnonischen Zeus



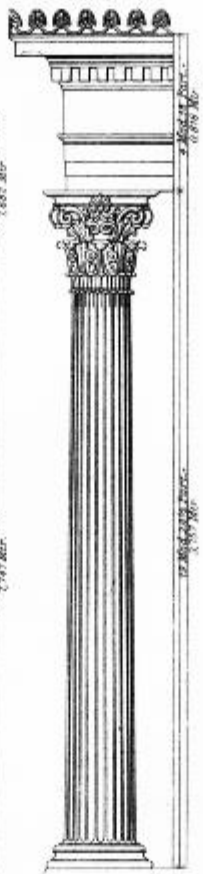
Vom Tempel am Ilissos in Athen



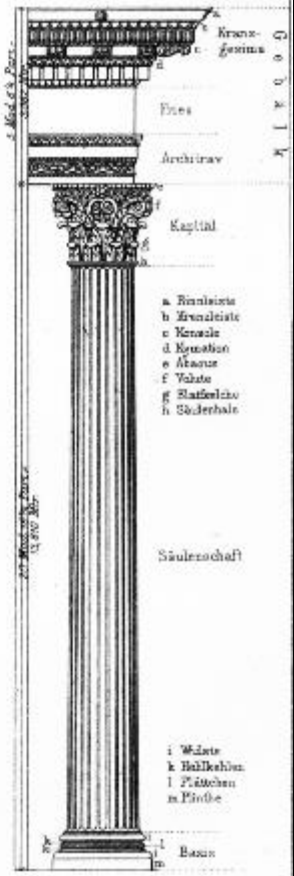
Vom Tempel d. Athene Polias in Priene



Vom Tempel d. Athene Polias in Athen



Vom Monument des Lysikrates in Athen.

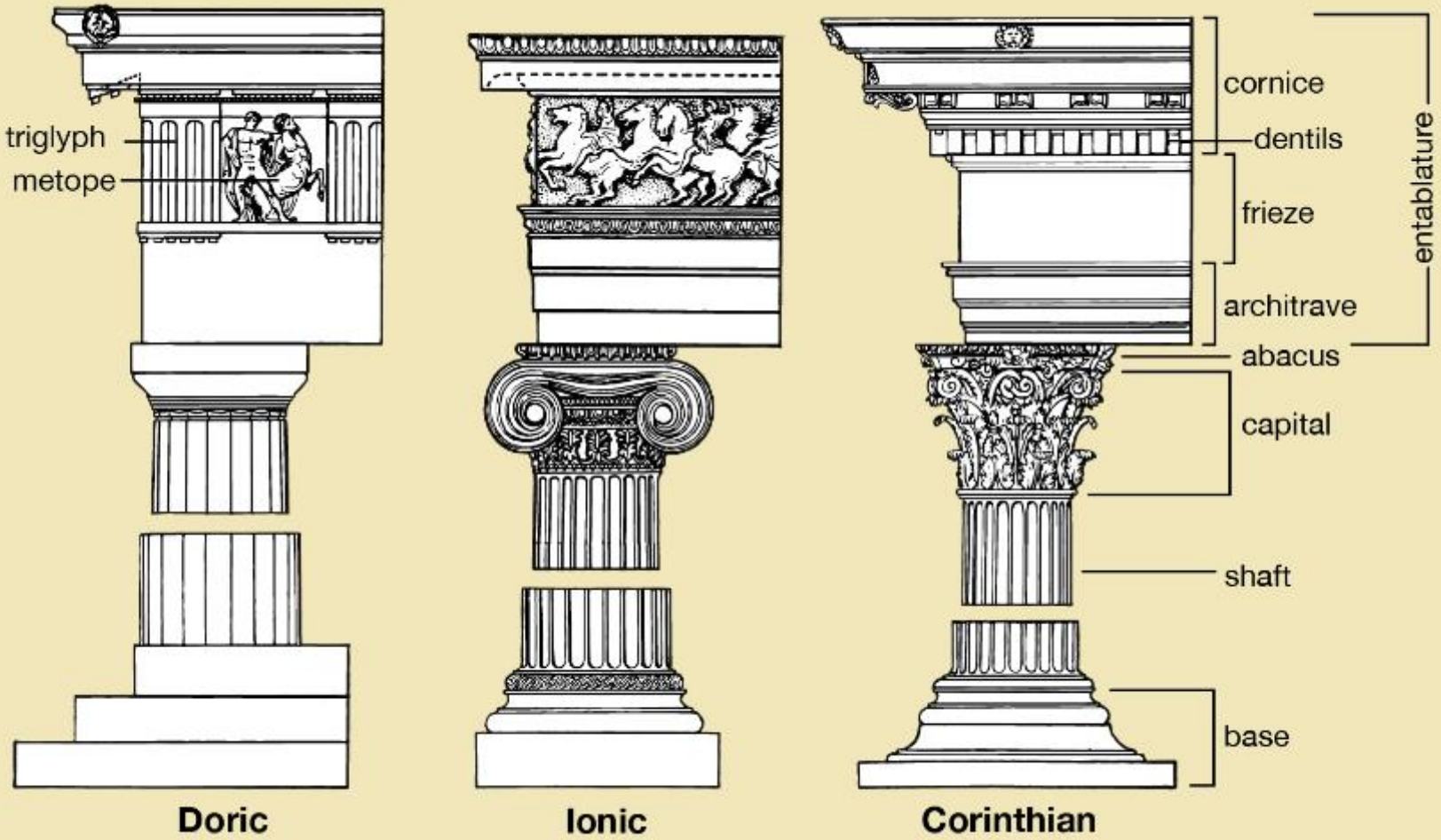


Vom Tempel d. Jupiter-Stator in Rom

Dorische Säulenordnung

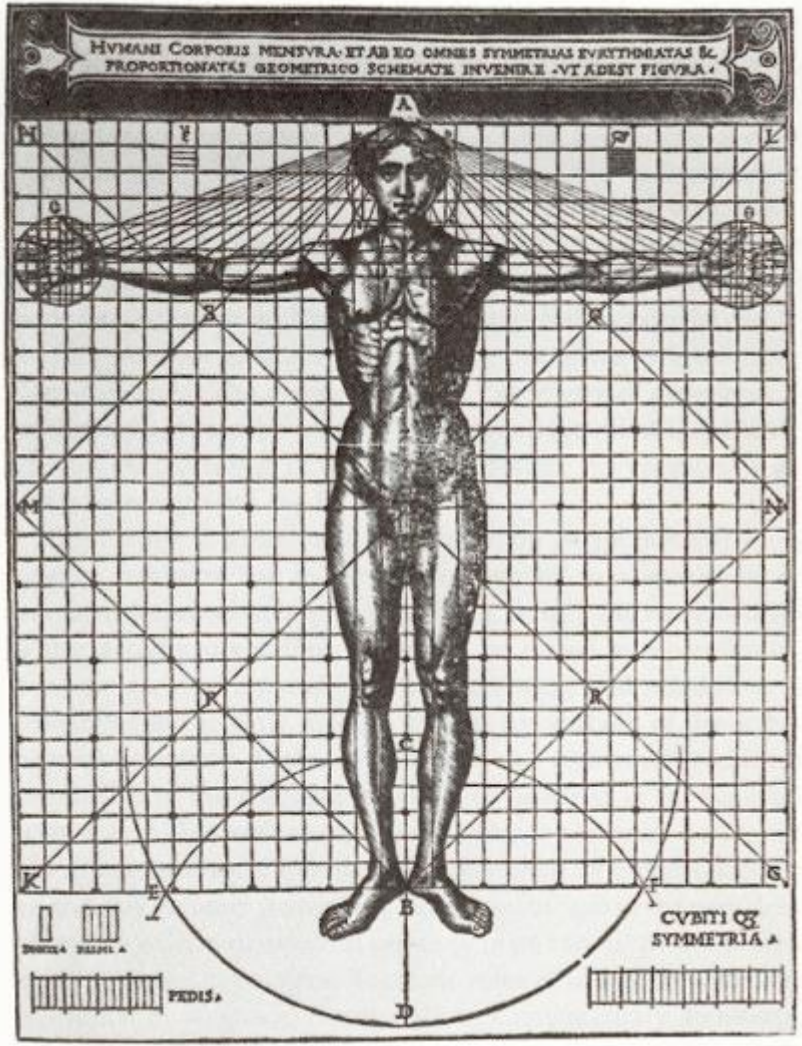
Jonische Säulenordnung

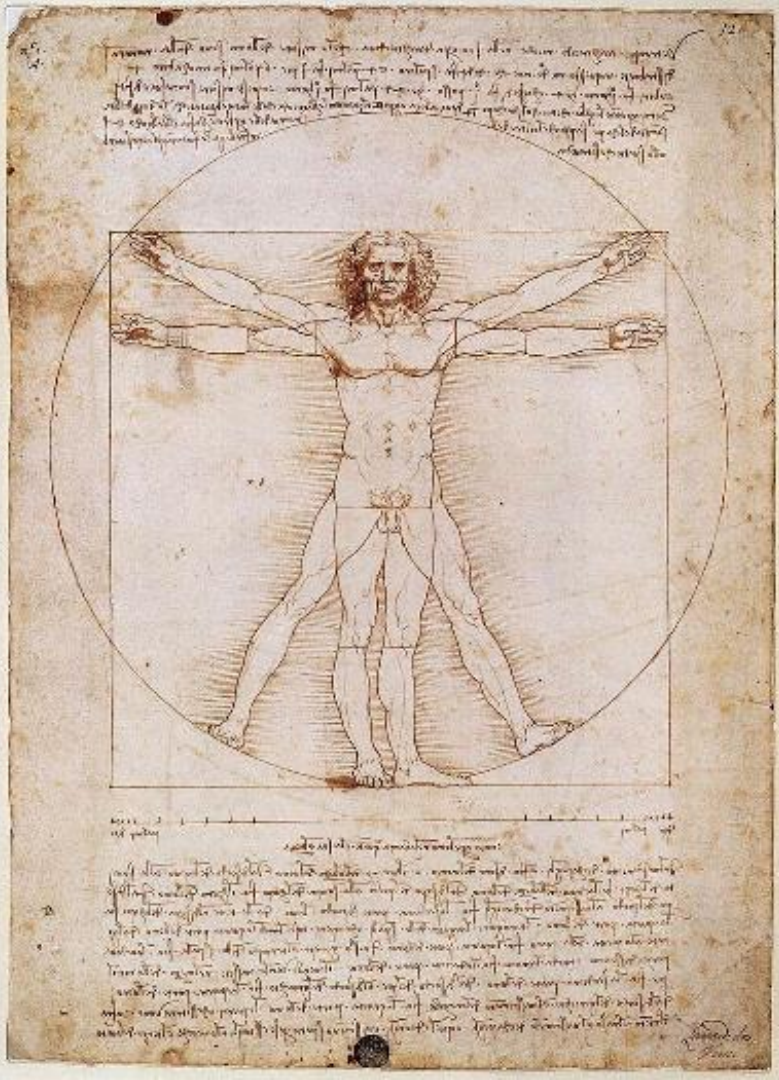
Korinthisch u. Römisch-Korinthisch

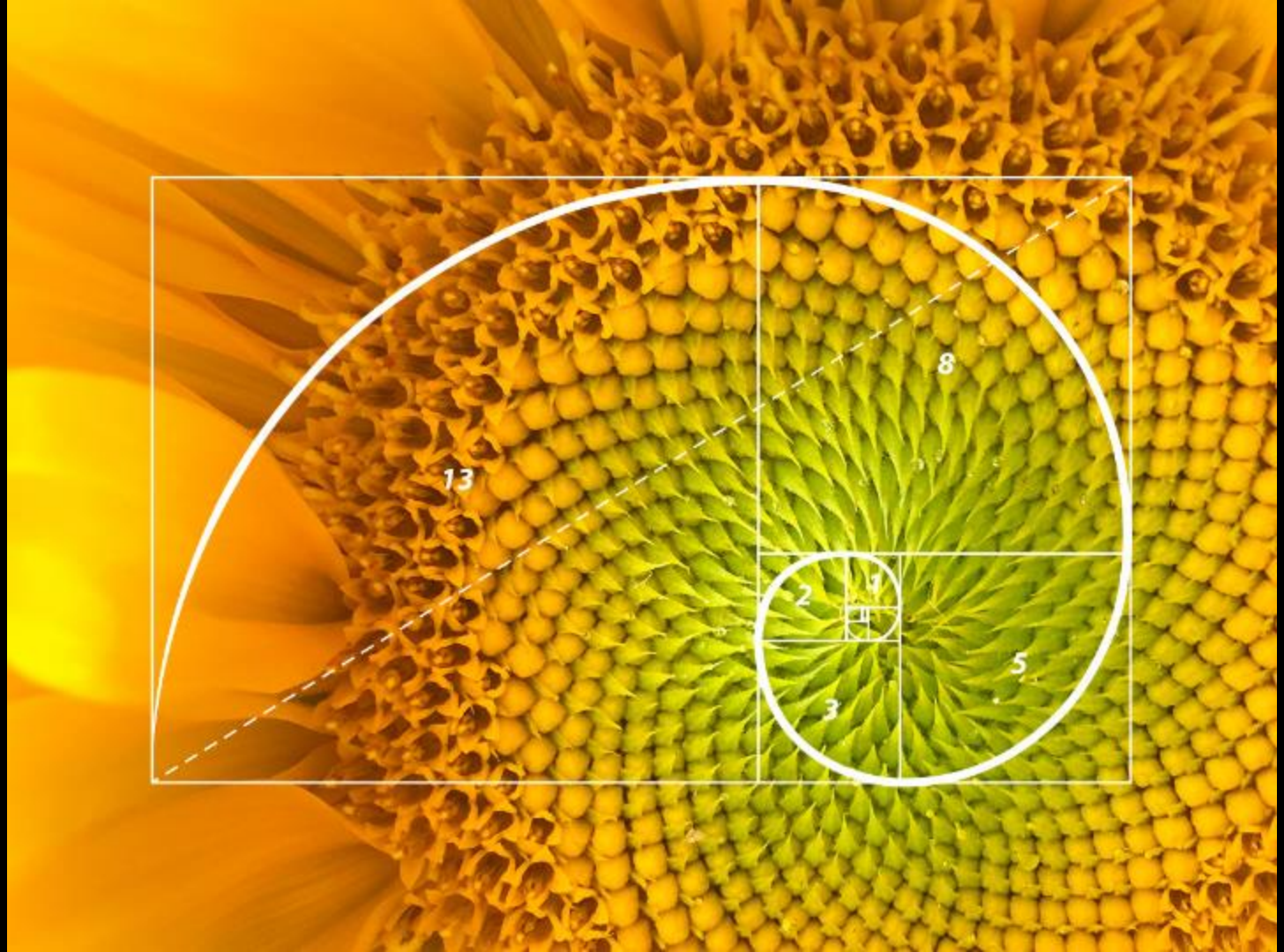


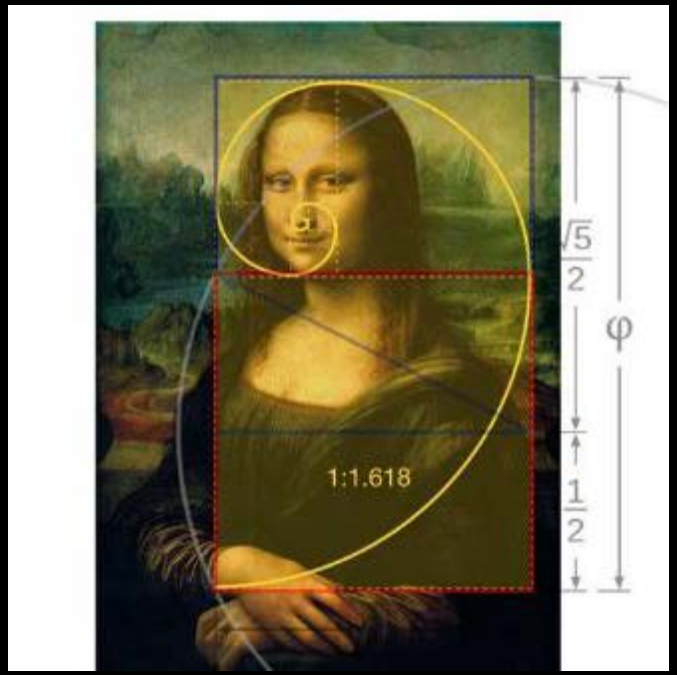
Golden ratio, also known as the golden section, golden mean, or divine proportion, in mathematics, the irrational number (1 + Square root of√5)/2, often denoted by the Greek letter ϕ or τ, which is approximately equal to 1.618.

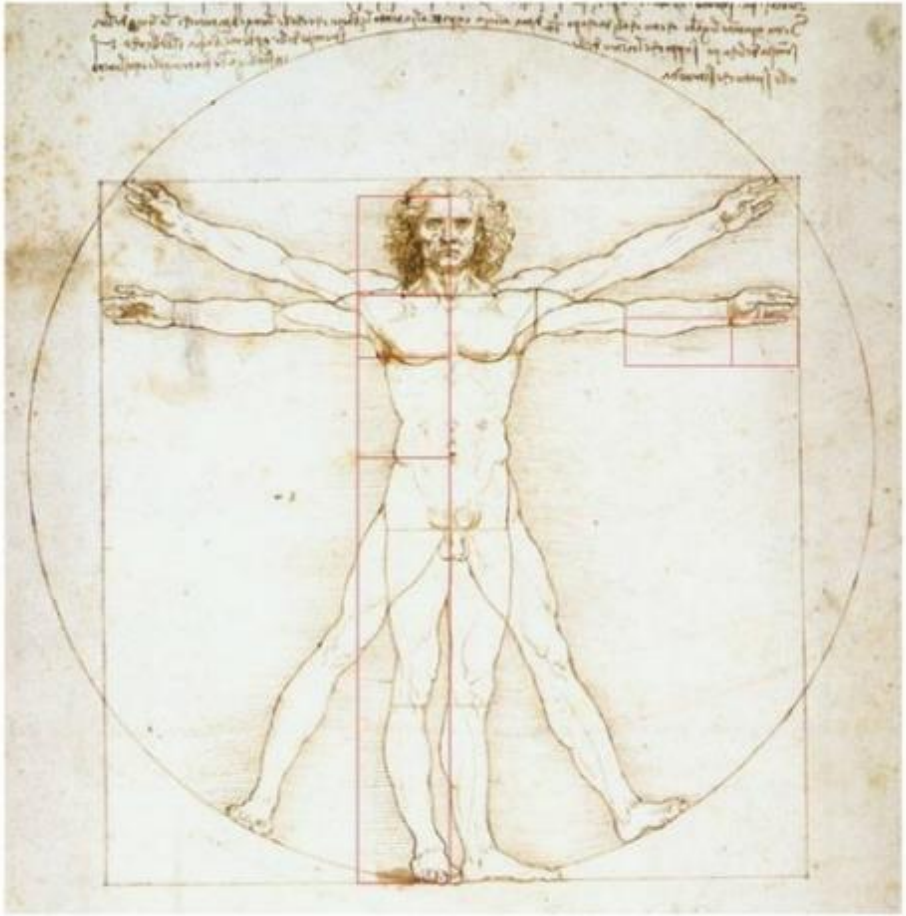
It is the ratio of a line segment cut into two pieces of different lengths such that the ratio of the whole segment to that of the longer segment is equal to the ratio of the longer segment to the shorter segment.

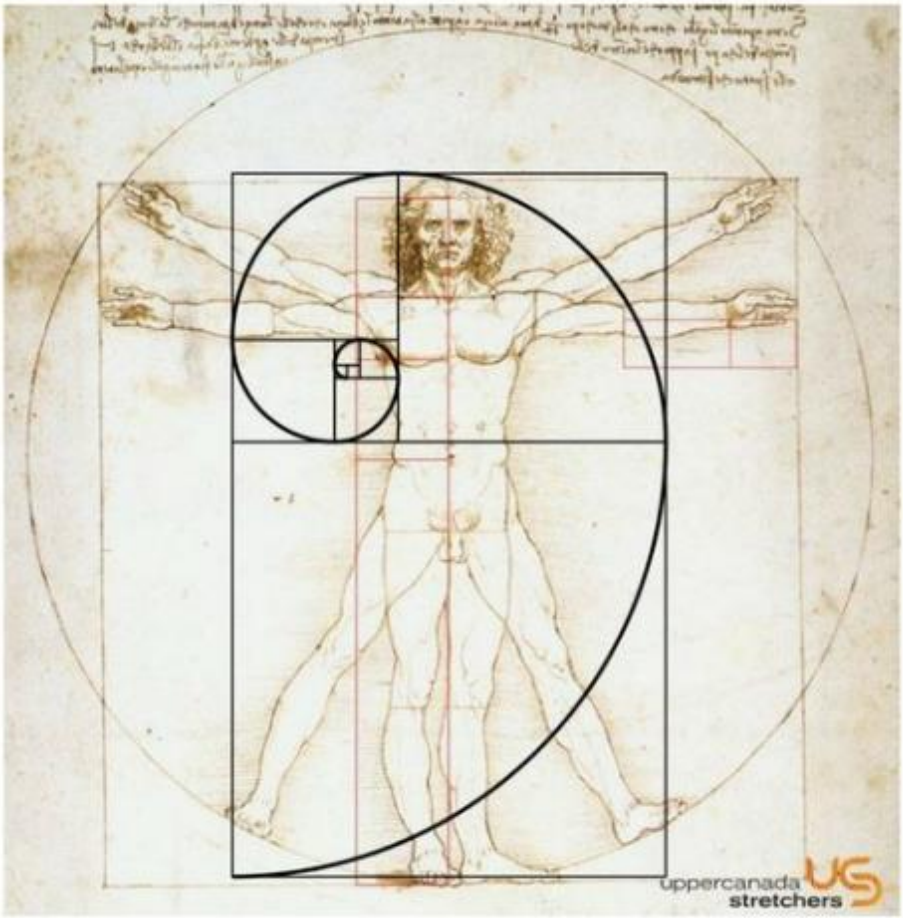

HVMANI CORPORIS MENSVRA. ET AB EO OMNES SYMMETRIAS EVRYTHMIAS ET PROPORTIONATAS GEOMETRICO SCHEMATE INVENIRE. VT ADEST FIGVRA.
CVBITI ET SYMMETRIA.
PEDIS.

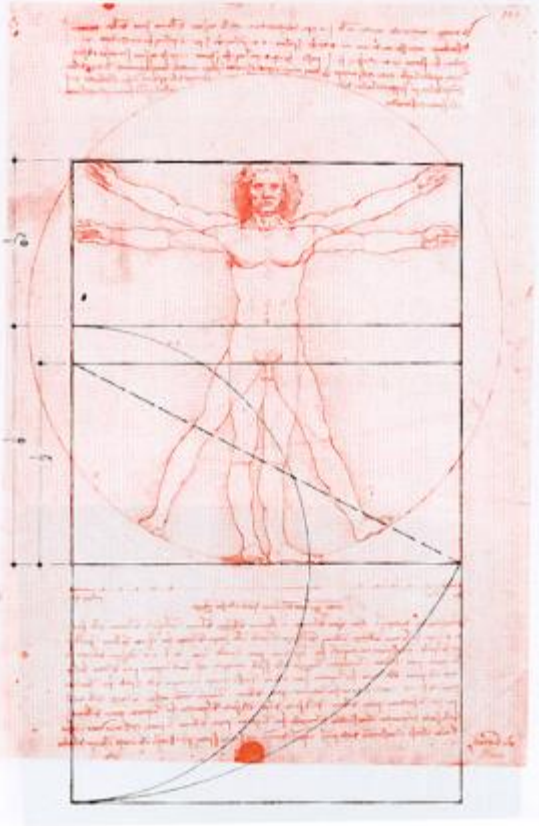


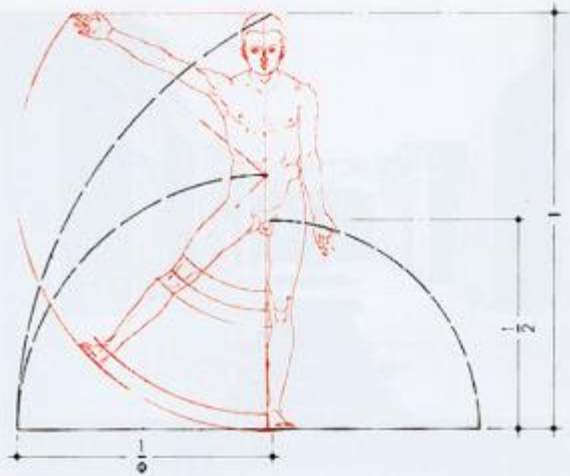

13
8
5
3
2
1


1:1.618
√5/2
φ
1/2

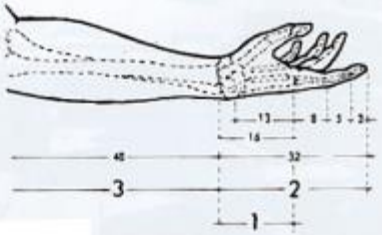



uppercanada
stretchers



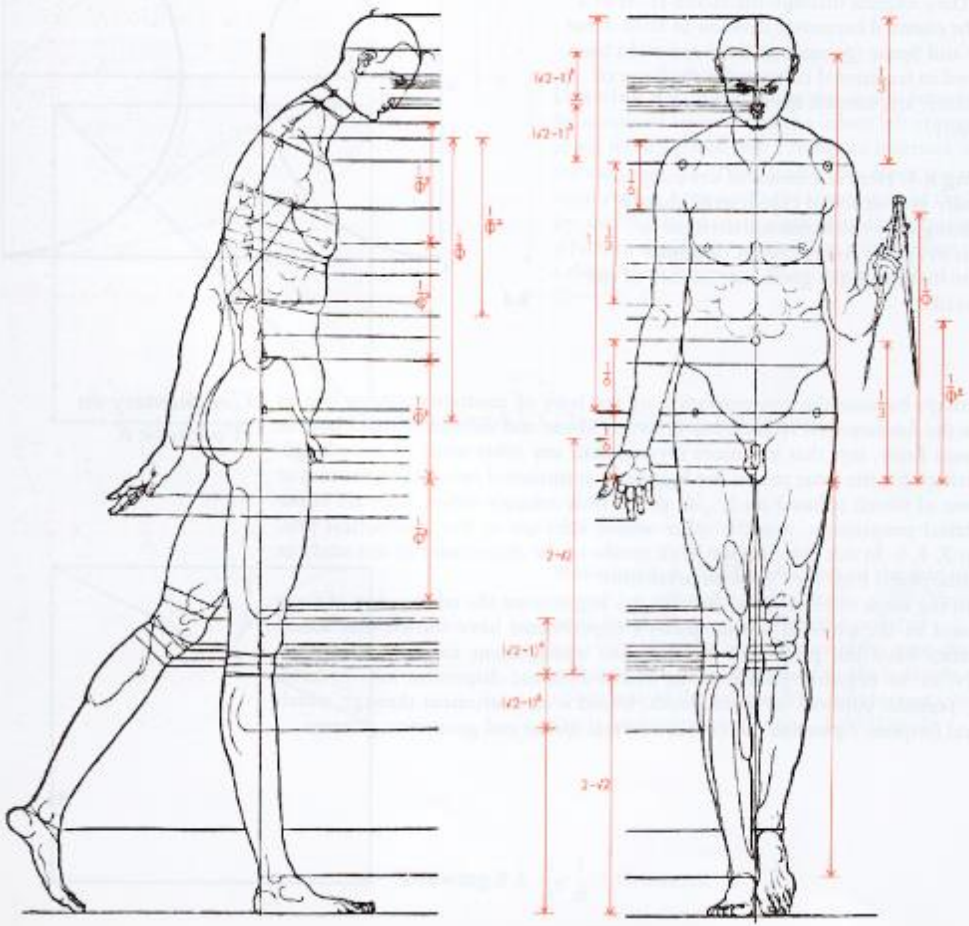


The canonical figures of both Leonardo da Vinci and Albrecht Dürer conform to the ancient biometric symbol of the body divided in half by the sex organ and by ϕ at the navel.

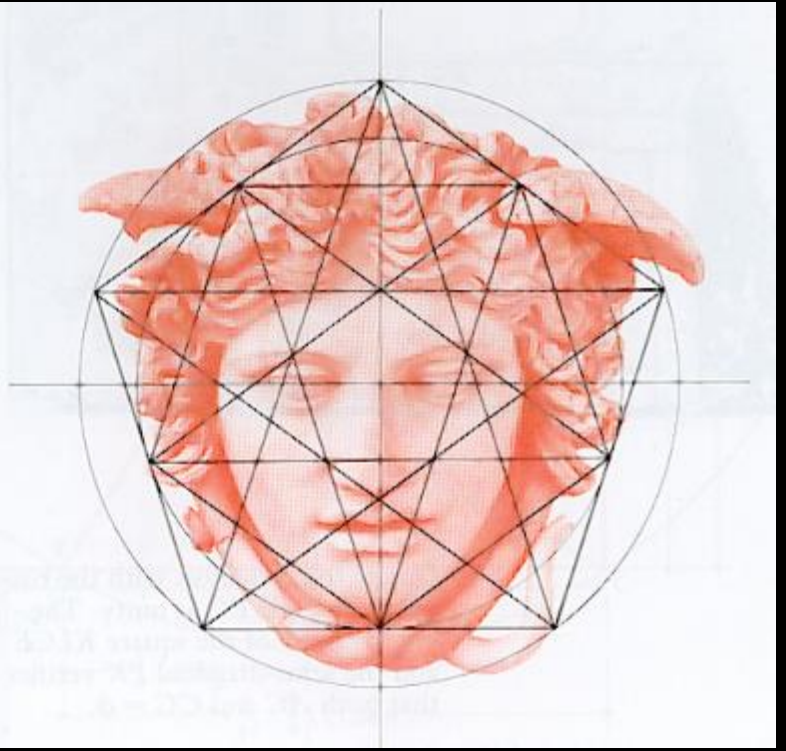


The appearance of the Fibonacci Series in the relationships between the bone-lengths of the human finger, hand and arm is another instance of the numerous ϕ relationships which occur in the human body.

Albrecht Dürer's human canon is entirely composed of proportions derived from the three unique divisions of Unity into the Arithmetic, Harmonic and Geometric Proportions.



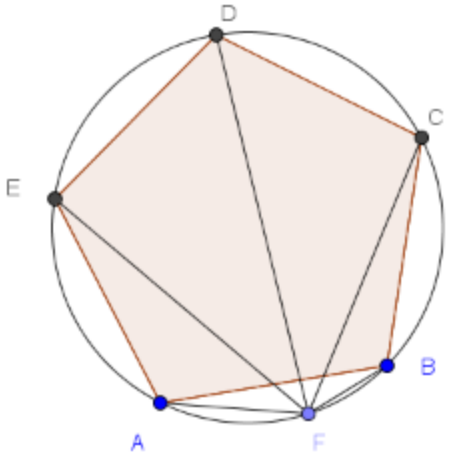
The Golden Divisions contained in the pentagram are shown to determine the proportions of this ancient mask of Hermes.

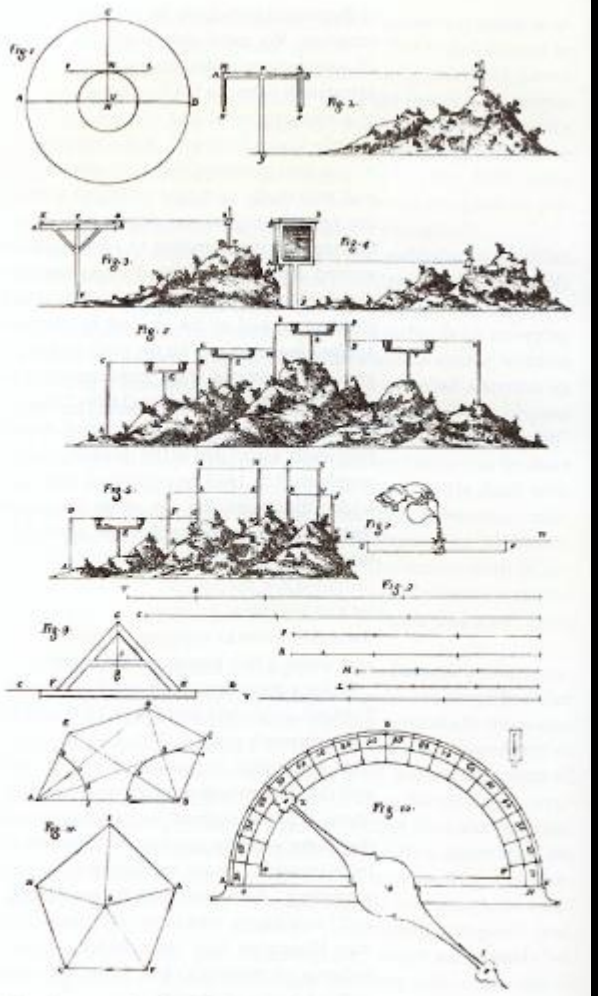


Let $ABCDE$ be a regular pentagon.

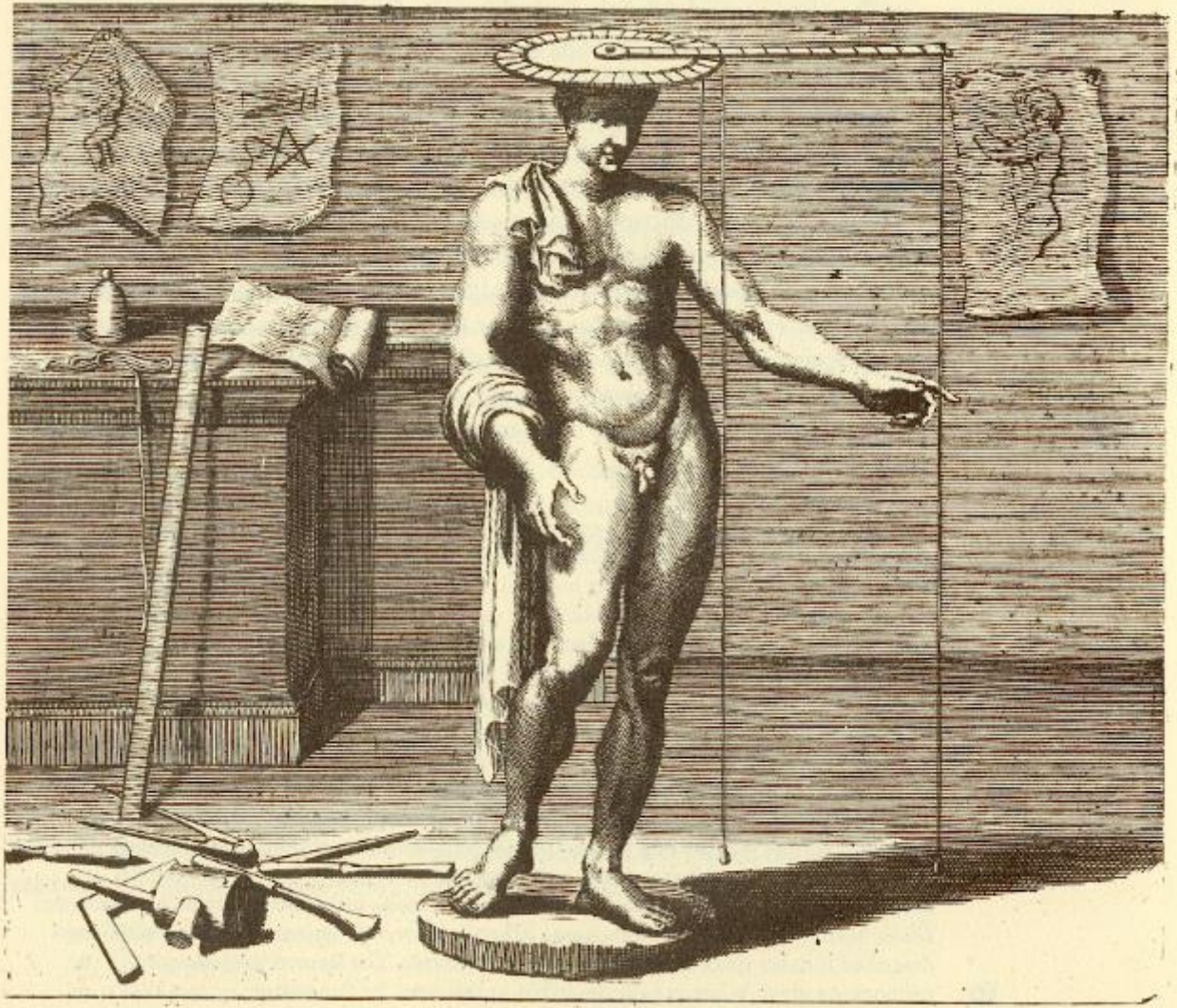
$$\varphi = \frac{FD}{FE + FC} = \frac{FB + FA}{FD} = \text{golden ratio}=0.618033\ldots;$$

and $FD + FB + FA = FE + FC$



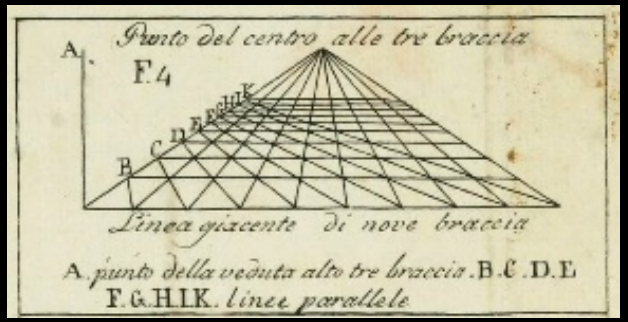


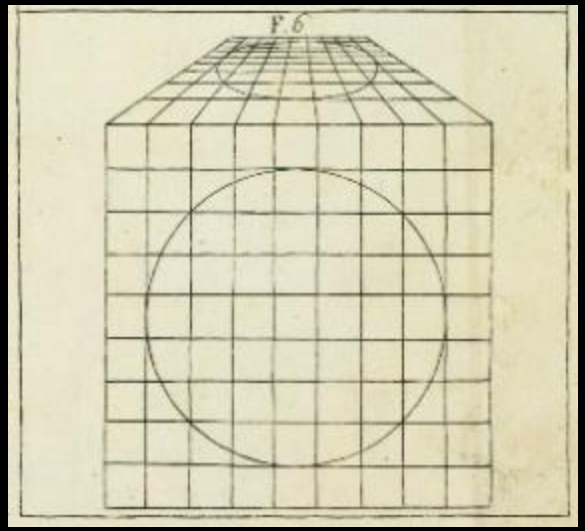
Surveying operations, from Guarini's *Architettura Civile*.

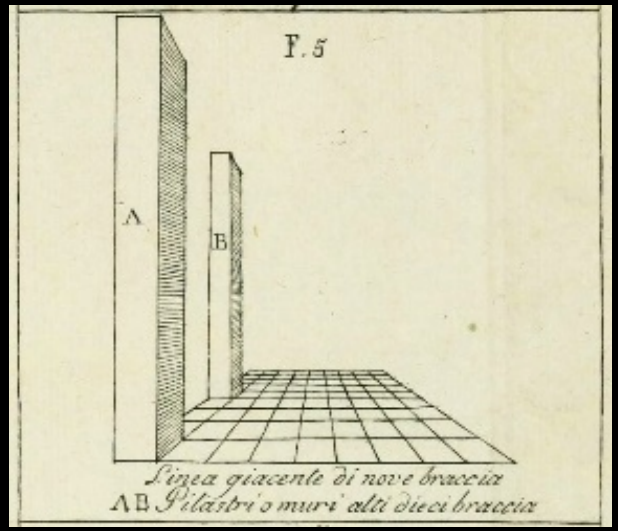


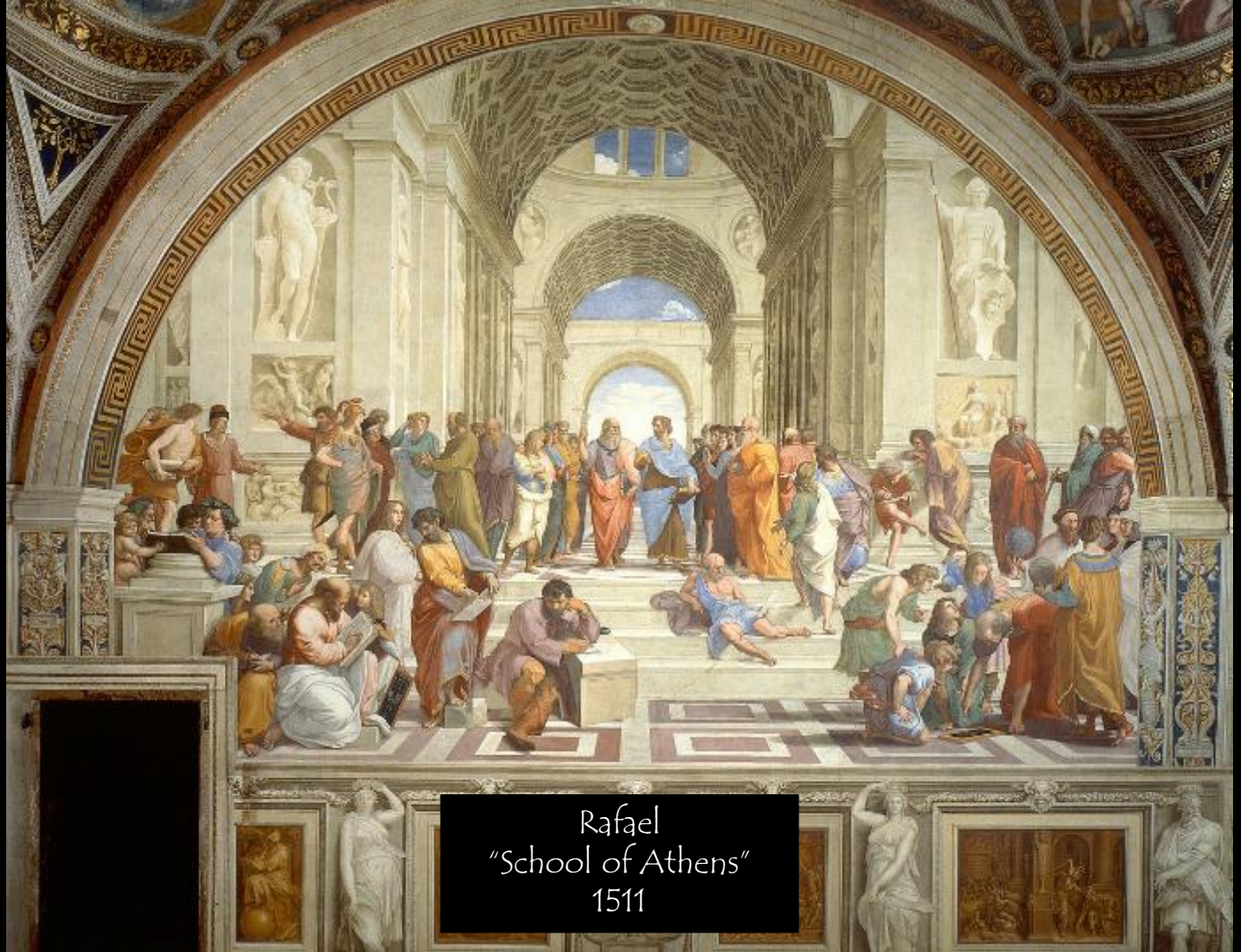
Leon Battista Alberti
Italian Renaissance Architect
1404 - 1472

Because of the distortion of perspective inevitable in a photograph, we can only roughly indicate a few of the basic ϕ proportions. But this entire edifice is based on ϕ and $\sqrt{2}$ relationships.

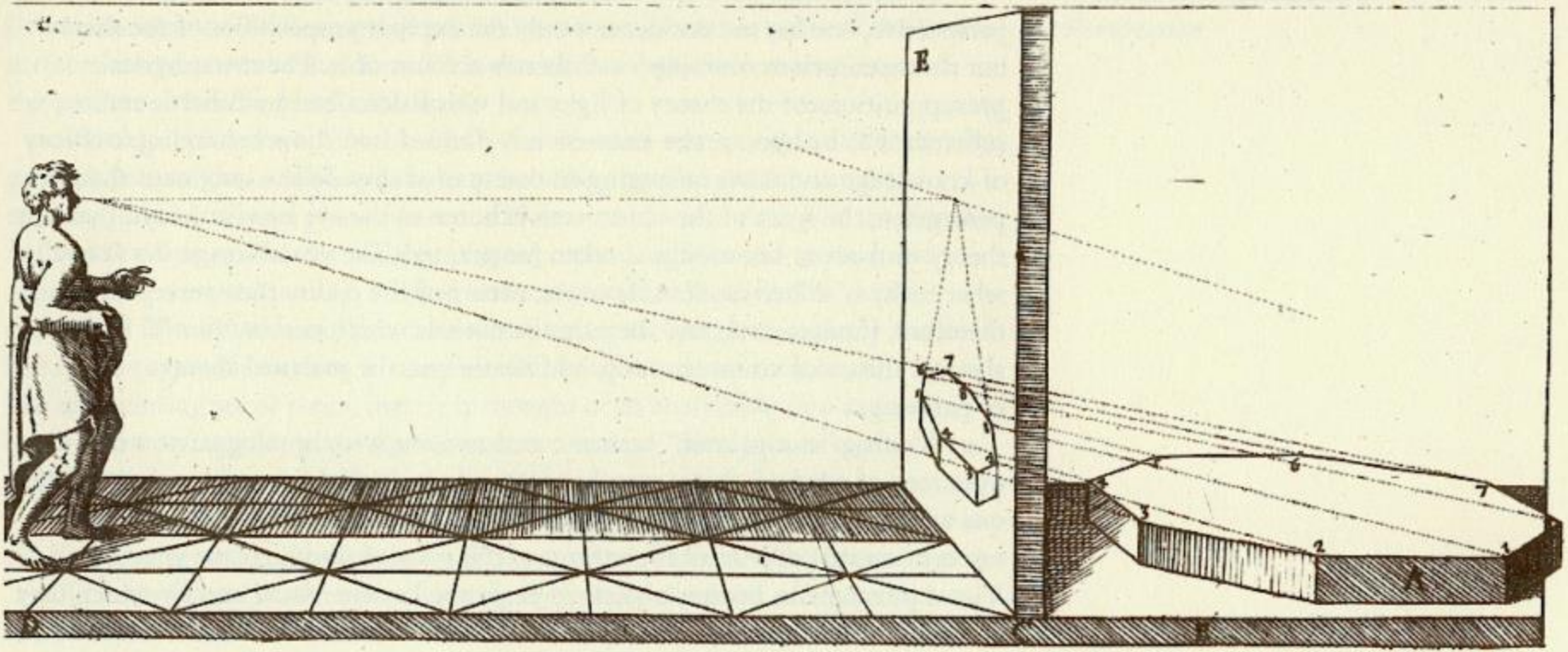

Punto del centro alle tre braccia
A
F.4
B
C
D
E
F
G
H
I
K
Linea giacente di nove braccia
A. punto della veduta alto tre braccia. B. C. D. E
F. G. H. I. K. linee parallele


F.6


F.5
A
B
Linea giacente di nove braccia
AB Pilastri o muri alti dieci braccia

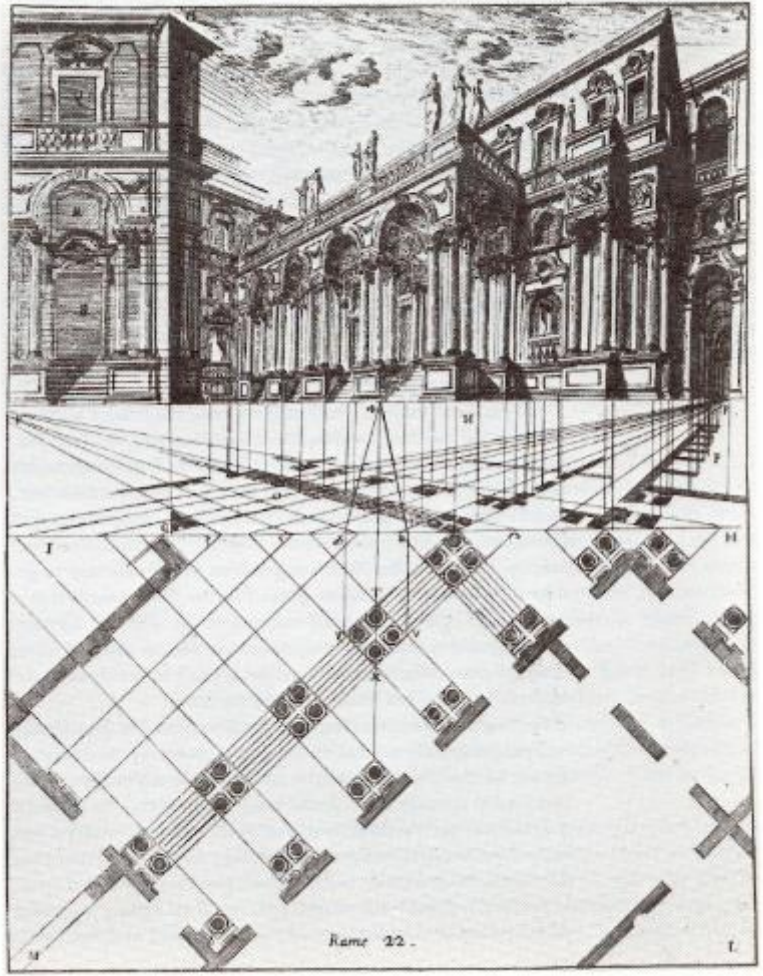


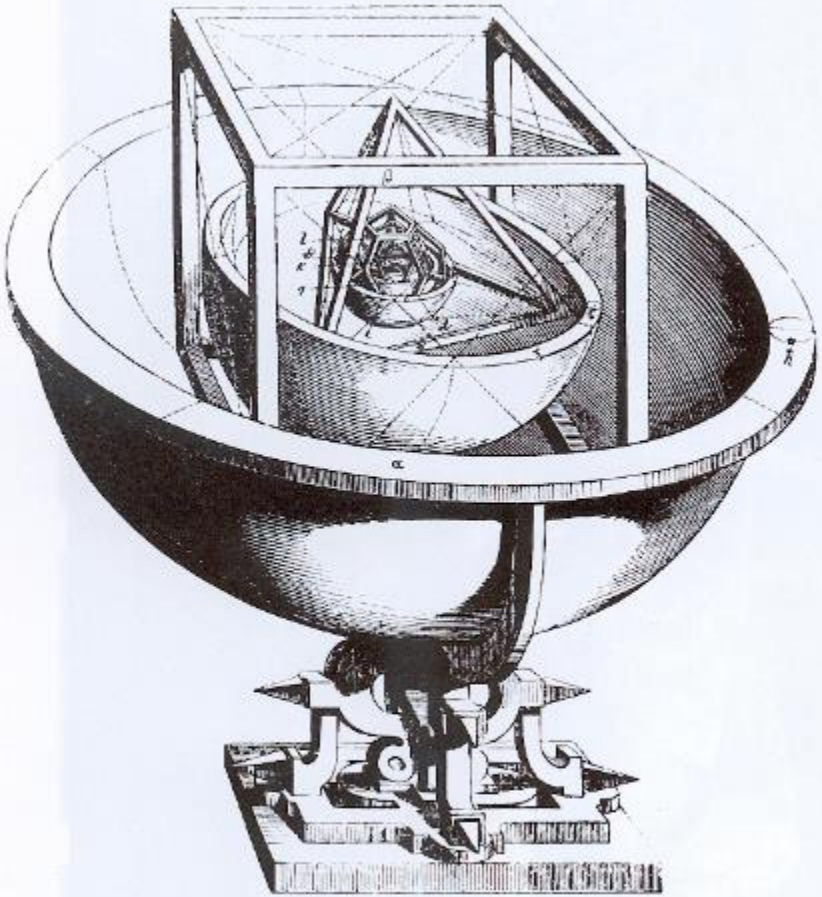
Rafael
"School of Athens"
1511



3. *Seeing by means of visual rays. From Vignola,* La due regole della prospettiva practica, *1611.*

An example of F. Galli-Bibiena's *scena per angolo*, from his own *Architettura Civile*.





Kepler's version of the solar system was as one Platonic solid within another, the radii of the intervening concentric spheres relating to the orbits of the planets.

Johannes Kepler
1571-1630

Renaissance marked a
return to Classicism

Pazzi Chapel
Florence, Italy
Filippo Brunelleschi
1443

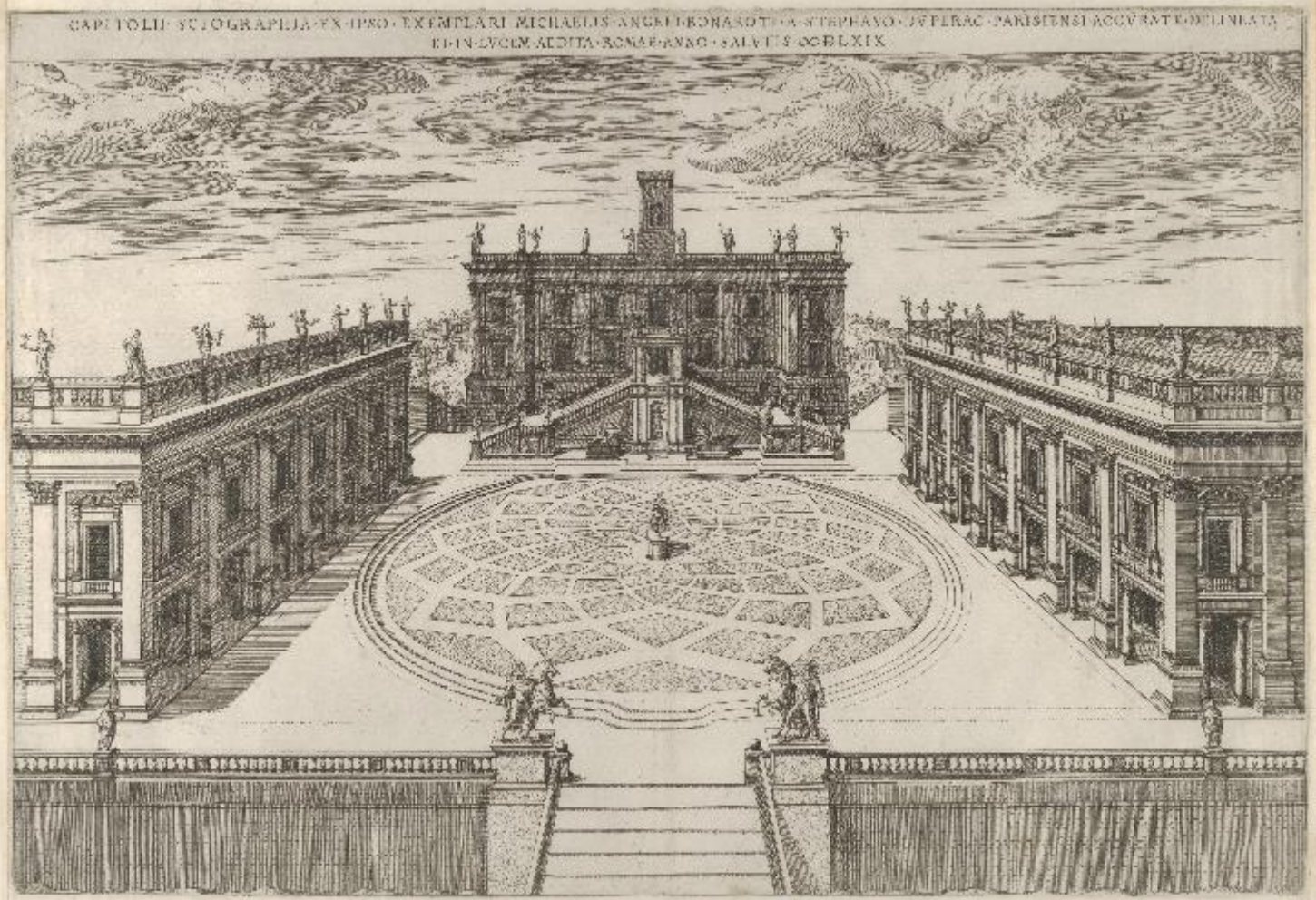
Ospedale degli Innocenti
Florence, Italy
Filippo Brunelleschi
1419

Donato
Bramante

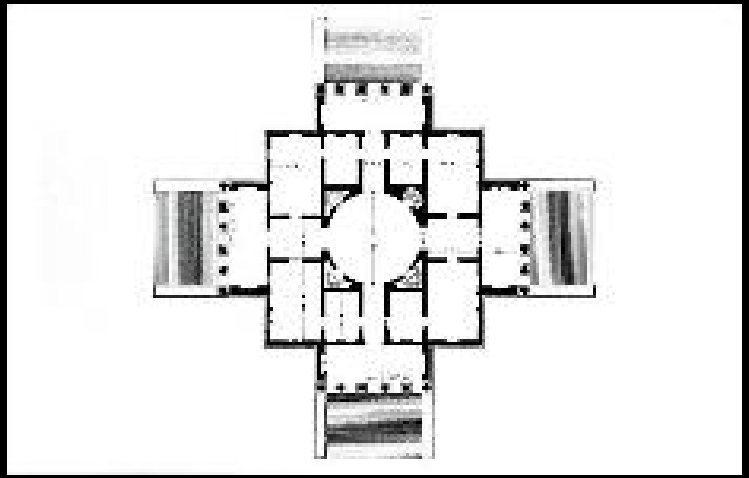
Tempietto
Rome 1502

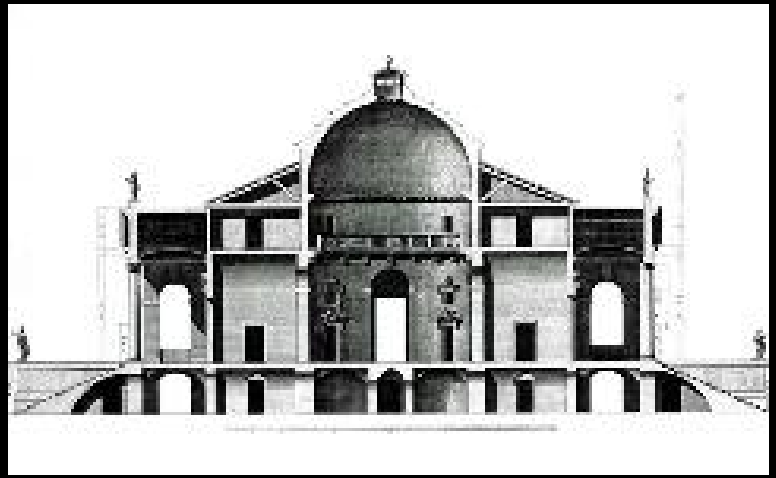
Capitaline Hill, Rome
Michelangelo (1475-1564)

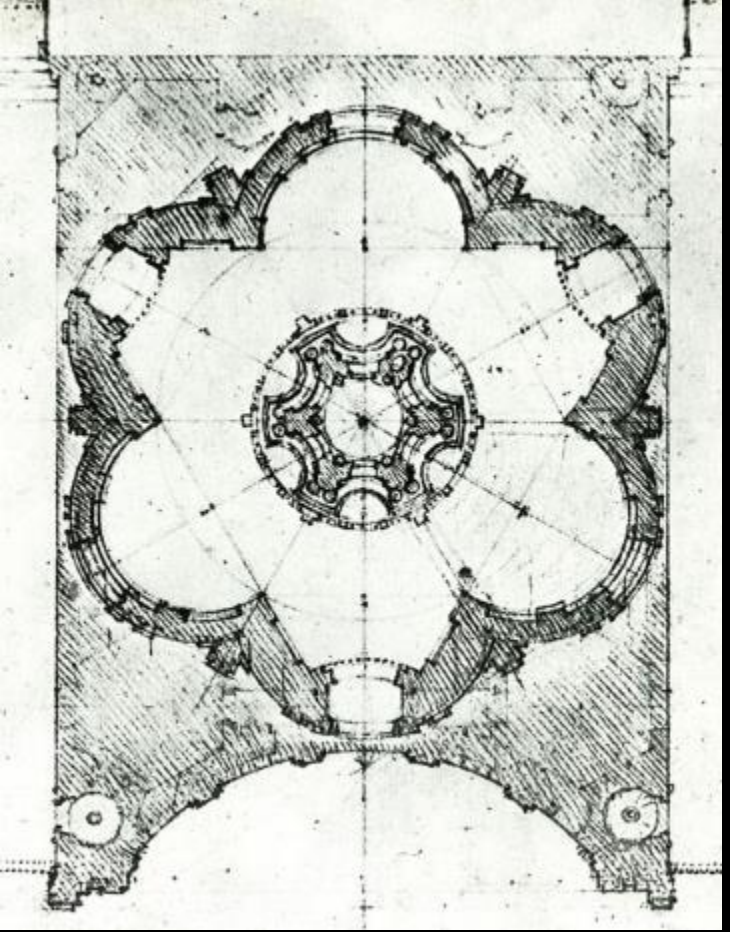
CAPITOLII SCIOGRAPHIA EX IPSO EXEMPLARI MICHAELIS ANGELI BONAROTI A STEPHANO DVPERAC PARISIENSI ACCVRATE DELINEATA
ET IN LVCEM AEDITA ROMAE ANNO SALVTIS MDLXIX



Villa Rotunda
Vicenza, Italy
Andrea Palladio
1592



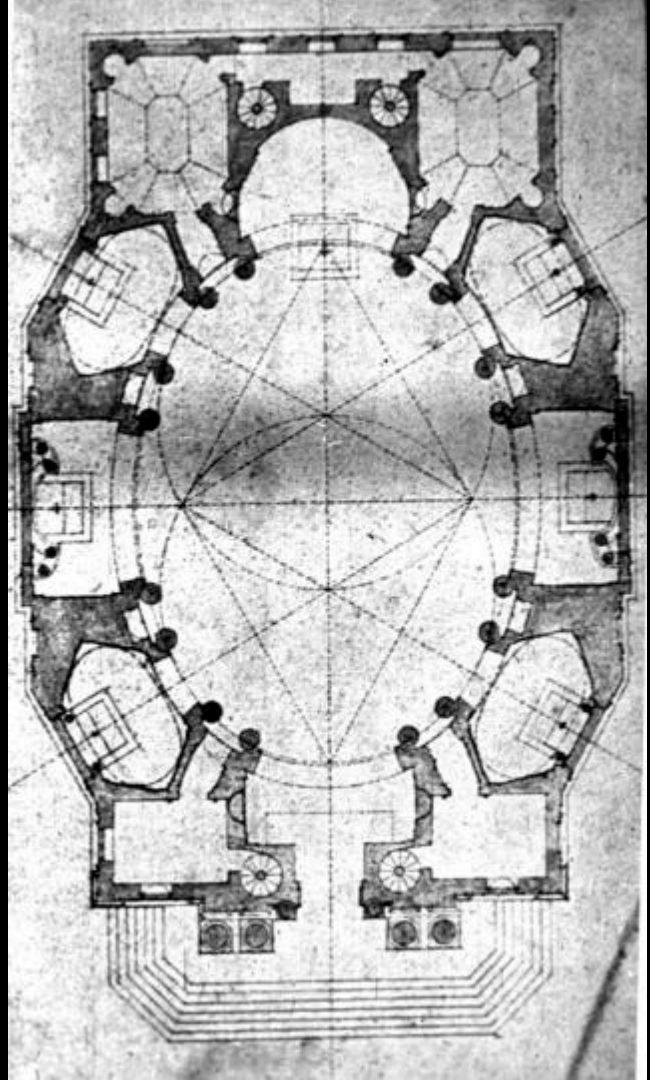




St Ivo alla Sapienza

Baroque Style
brought about
more complex
geometries
exemplified in the
work of Francesco
Borromini
1599-1667

San Carlo alle Quatro Fontane



Francesco Borromini
St. Ivo all Sapienza
Rome
1642-1660


San Carlo alle
Quatro Fontane


The Enlightenment
1685-1815

St. Martin in the Fields
London, England
James Gibbs
1726

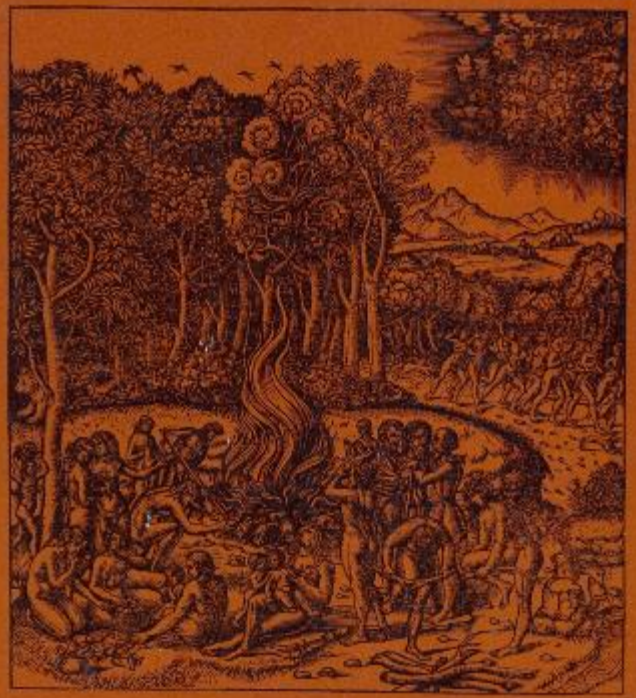

St. Paul's Cathedral
London, England
Christopher Wren
1711

On Adam's House in Paradise

THE IDEA OF THE PRIMITIVE HUT
IN ARCHITECTURAL HISTORY

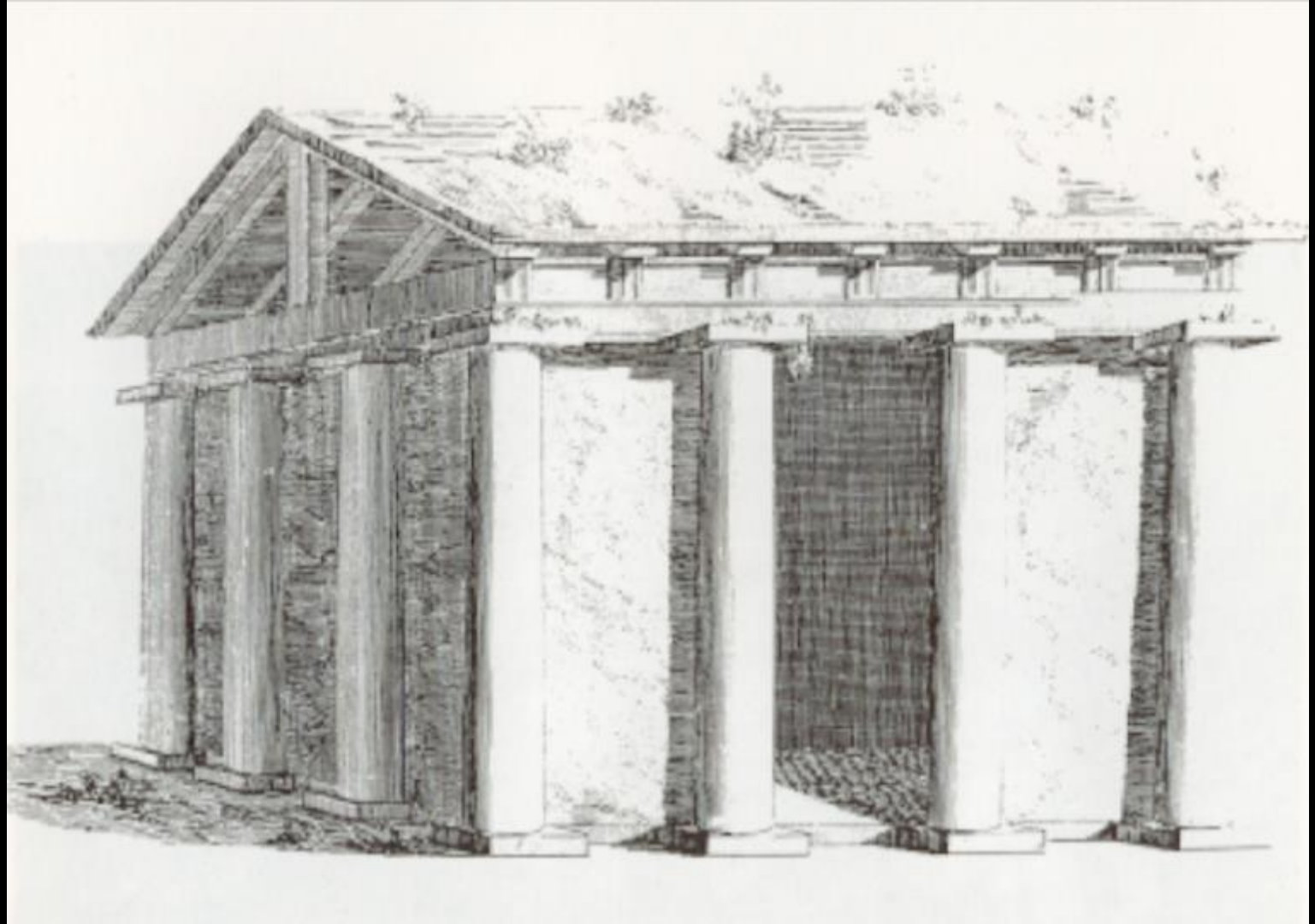
Second edition

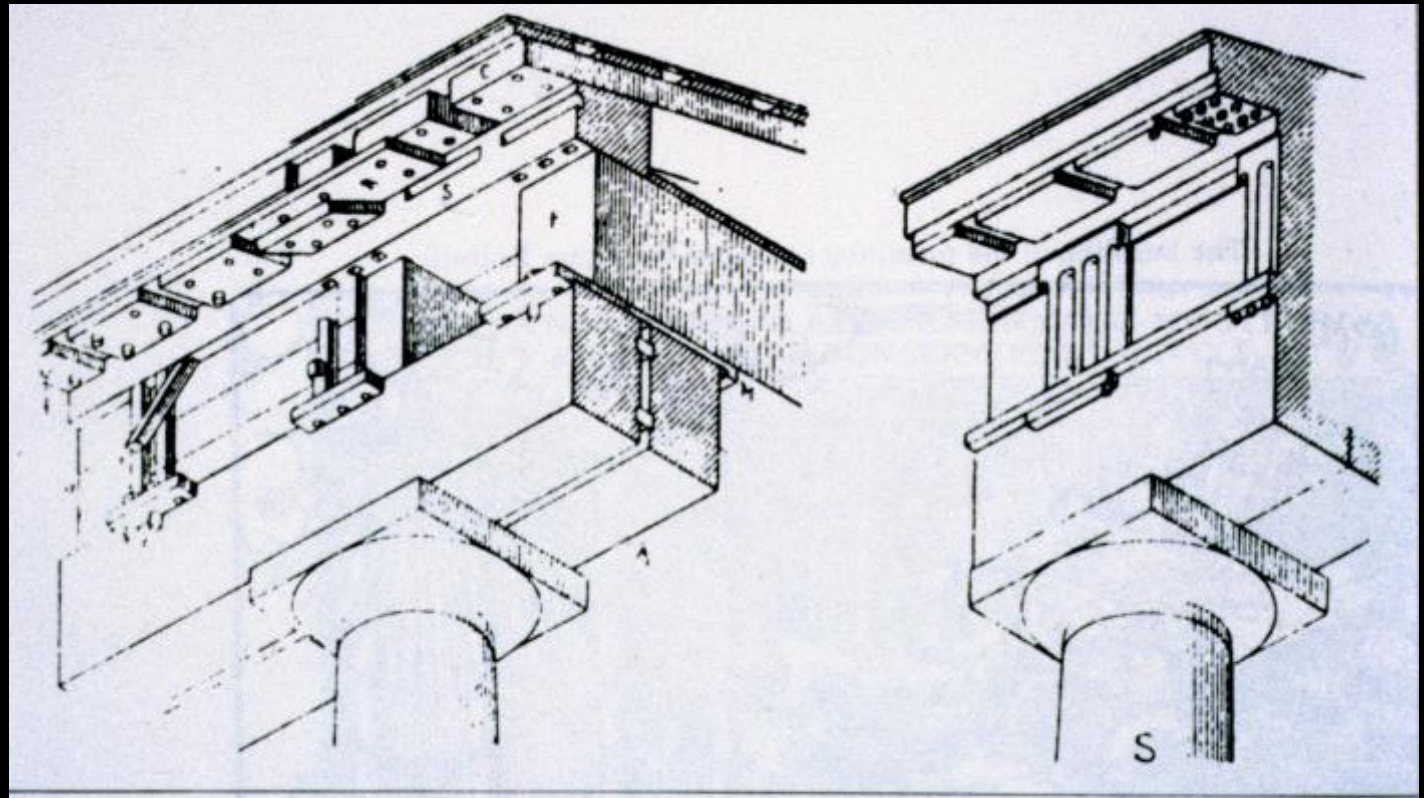
JOSEPH RYKWERT



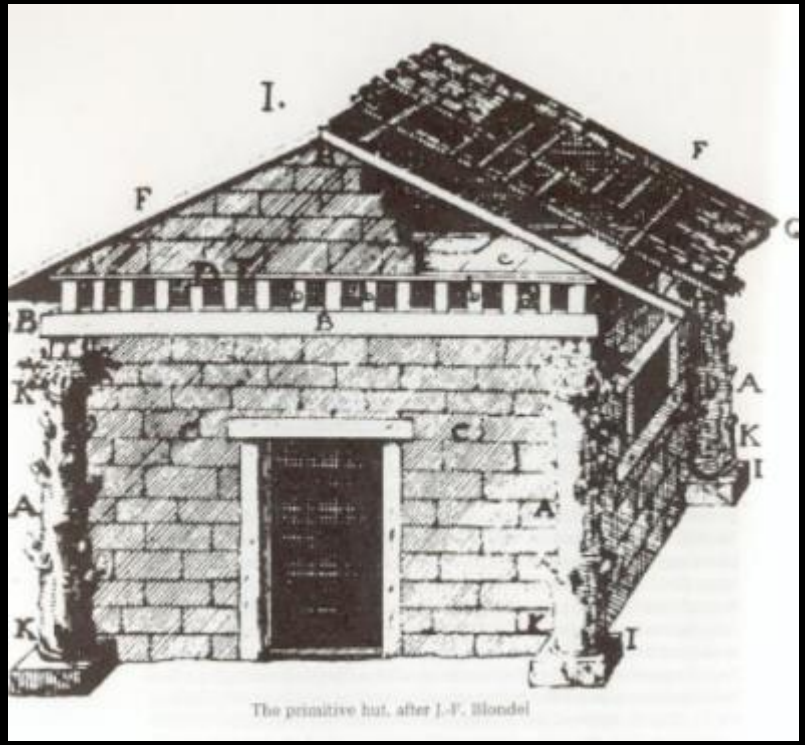
The personification of architecture and the primitive hut, after Laugier

Abbe Marc-Antoine Laugier
Jesuit Priest and architectural theorist
1713 to 1769



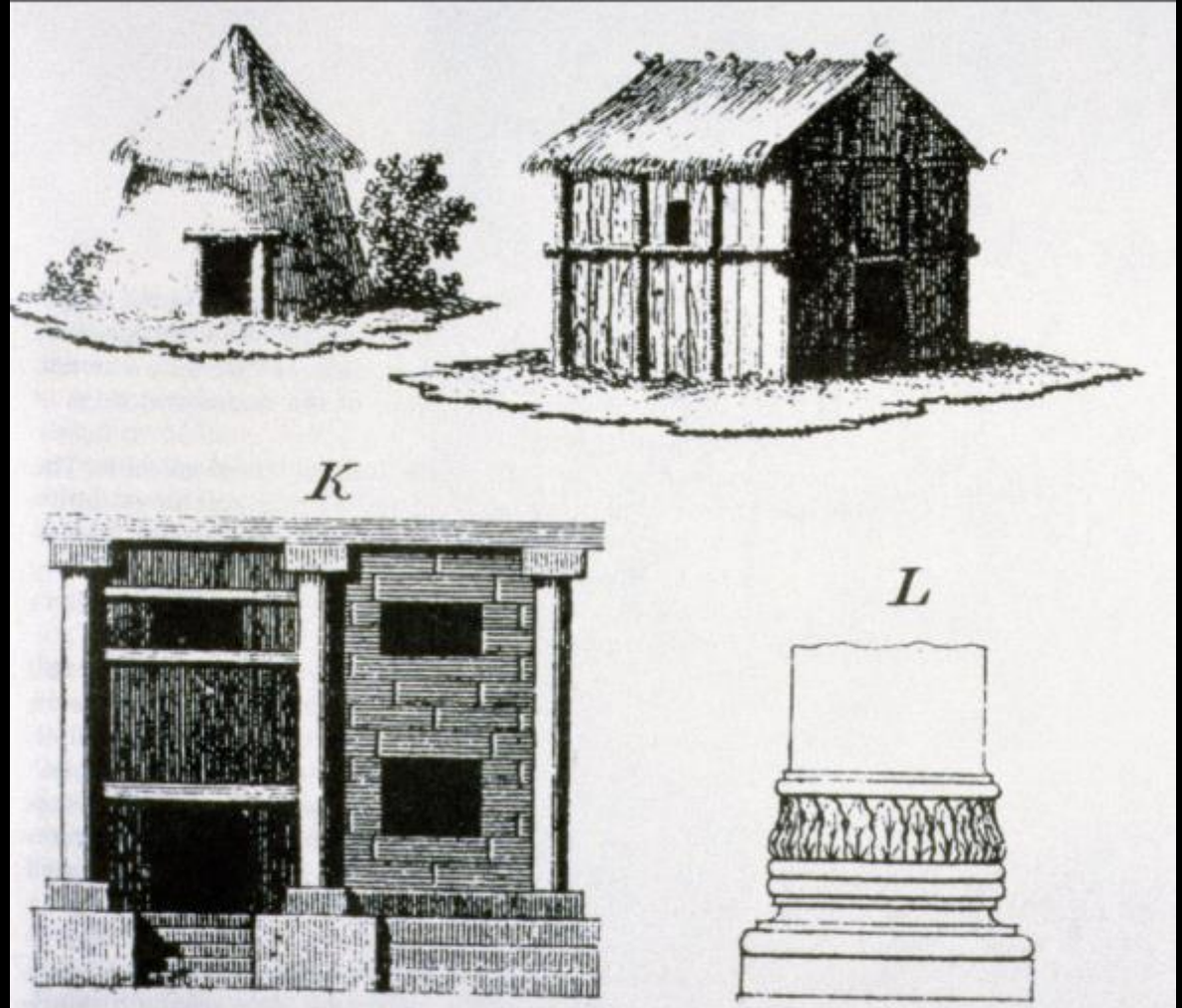


Stone and reconstructed timber origin of Doric order, after Choisy

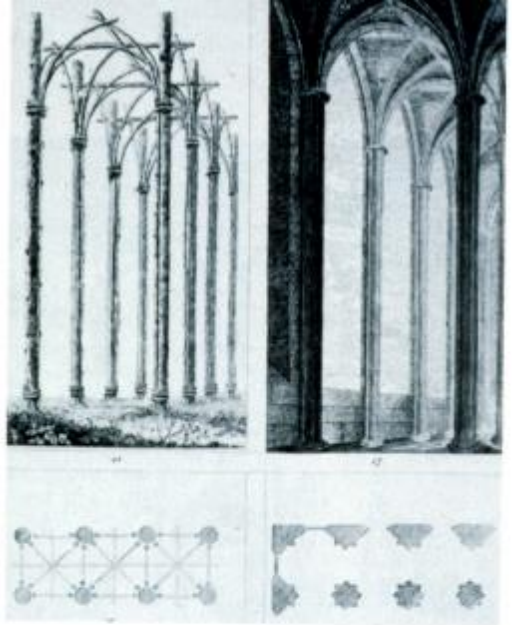


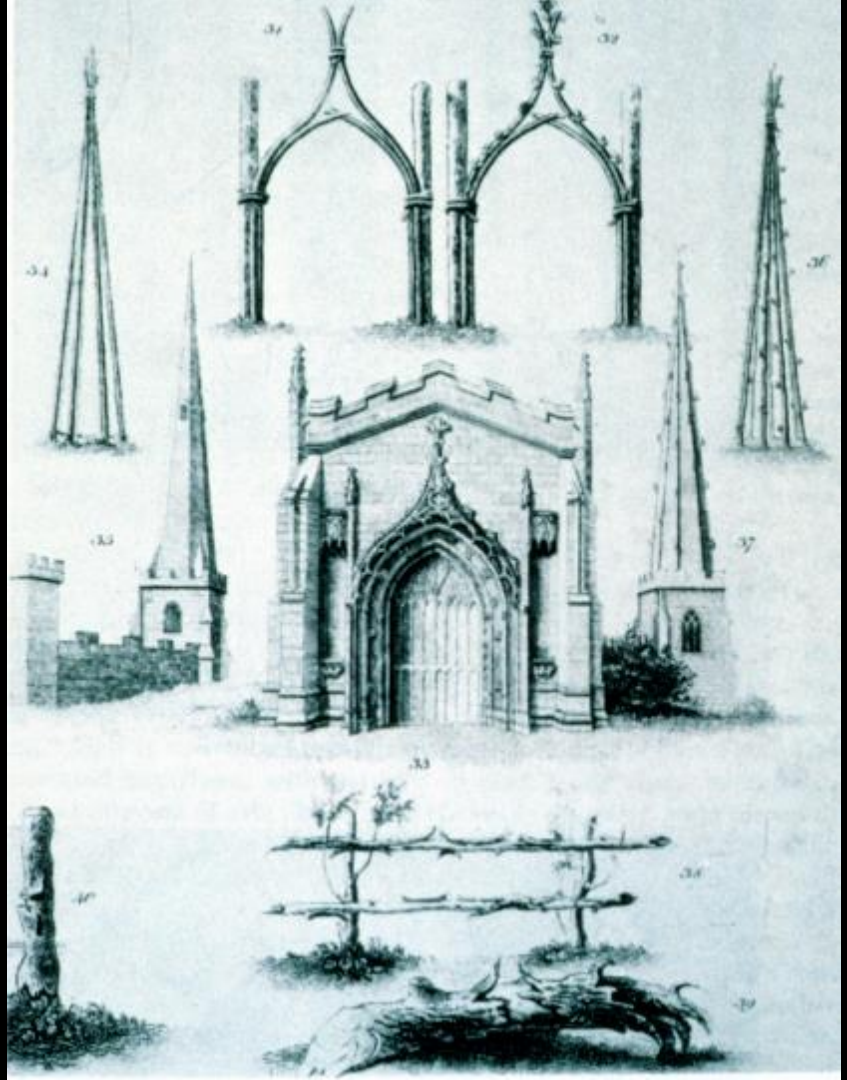
The primitive hut, after J.-F. Blondel

this page and opposite:
Primitive huts and the origin of architecture, after Chambers



Primitive huts and the origin of the orders, after Milizia

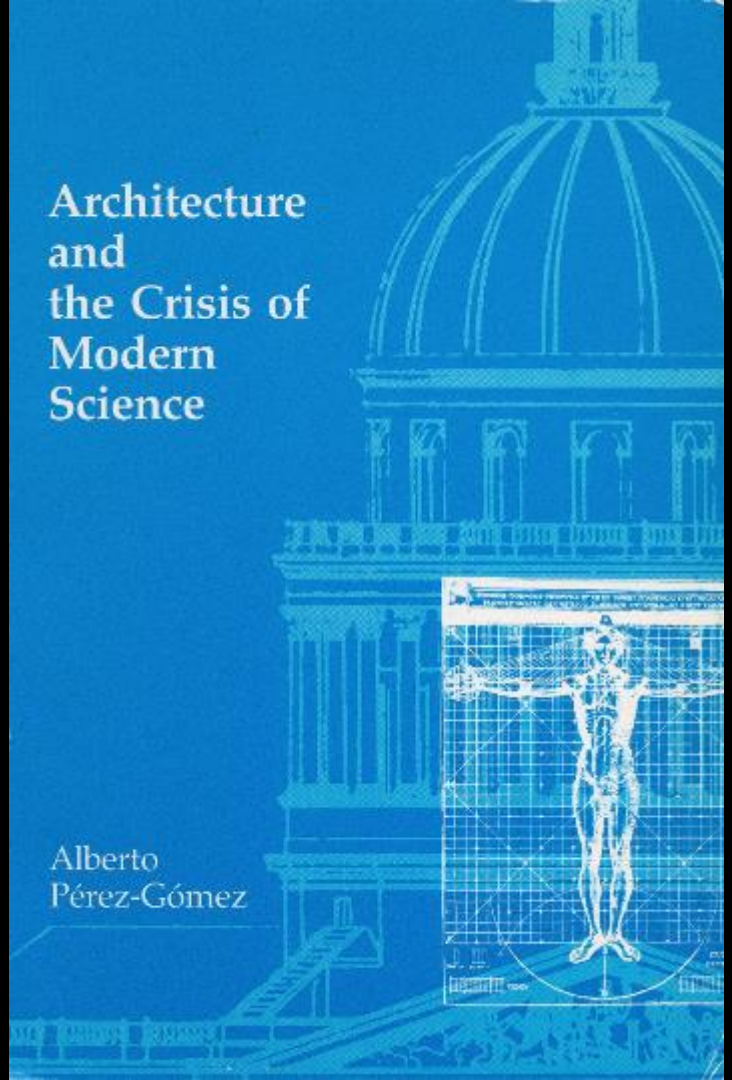




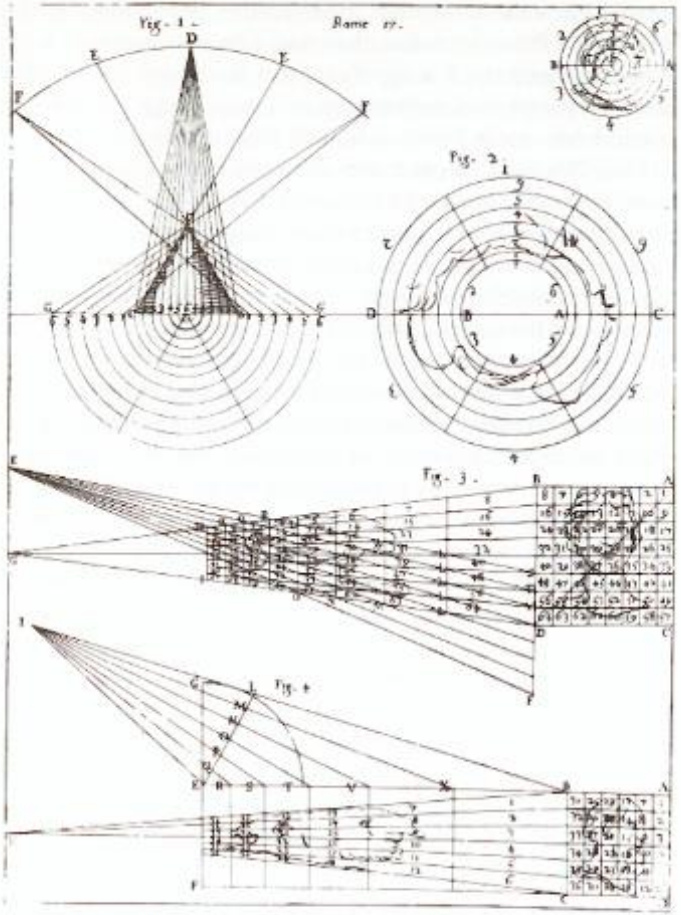
Barcelona Cathedral
Barcelona, Spain
1298

Architecture and the Crisis of Modern Science

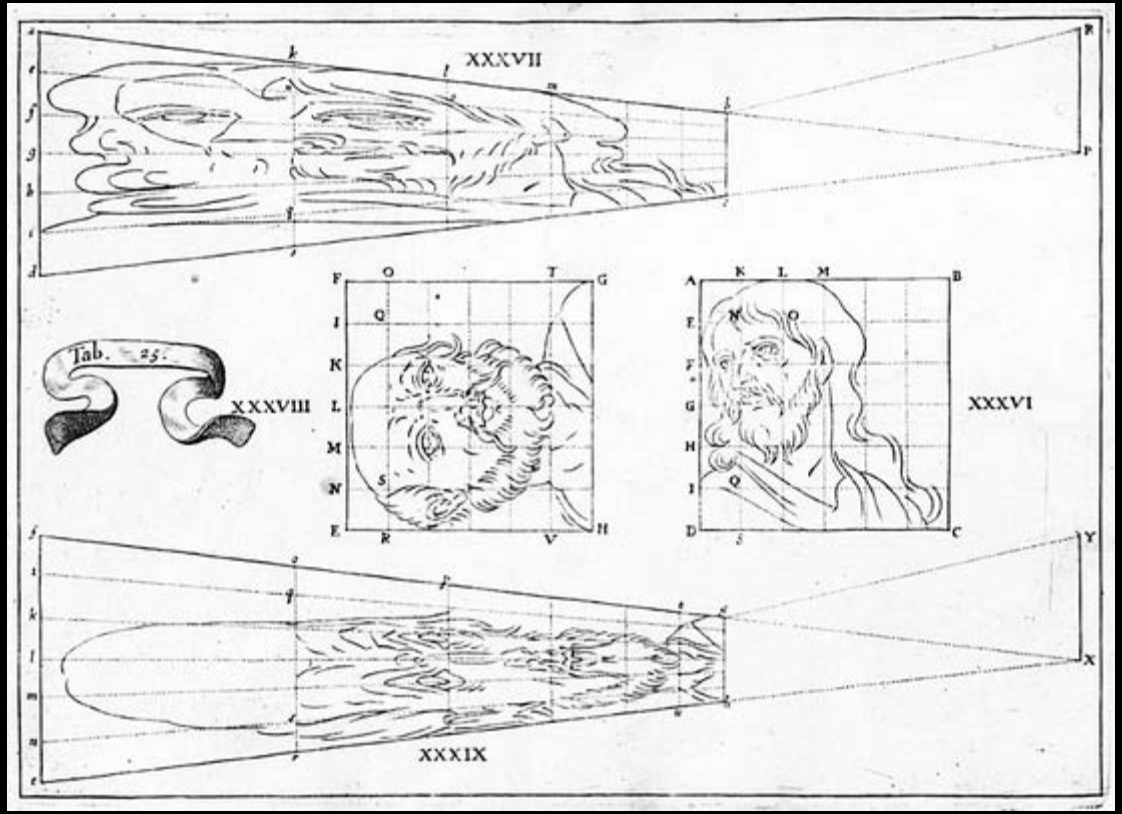
Alberto Pérez-Gómez




anamorphosis

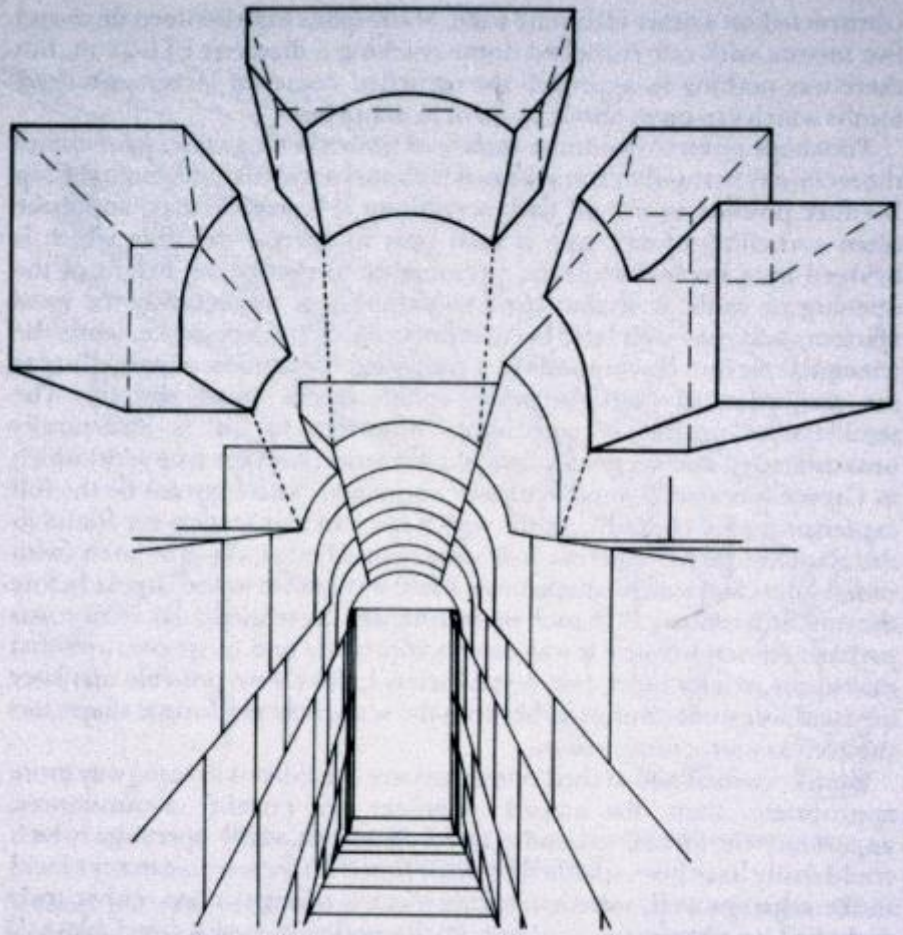


Anamorphosis as a scientific curiosity, from F. Galli-Bibiena's *Architettura Civile*.


XXXVII
Tab. 25.
XXXVIII
XXXVI
XXXIX

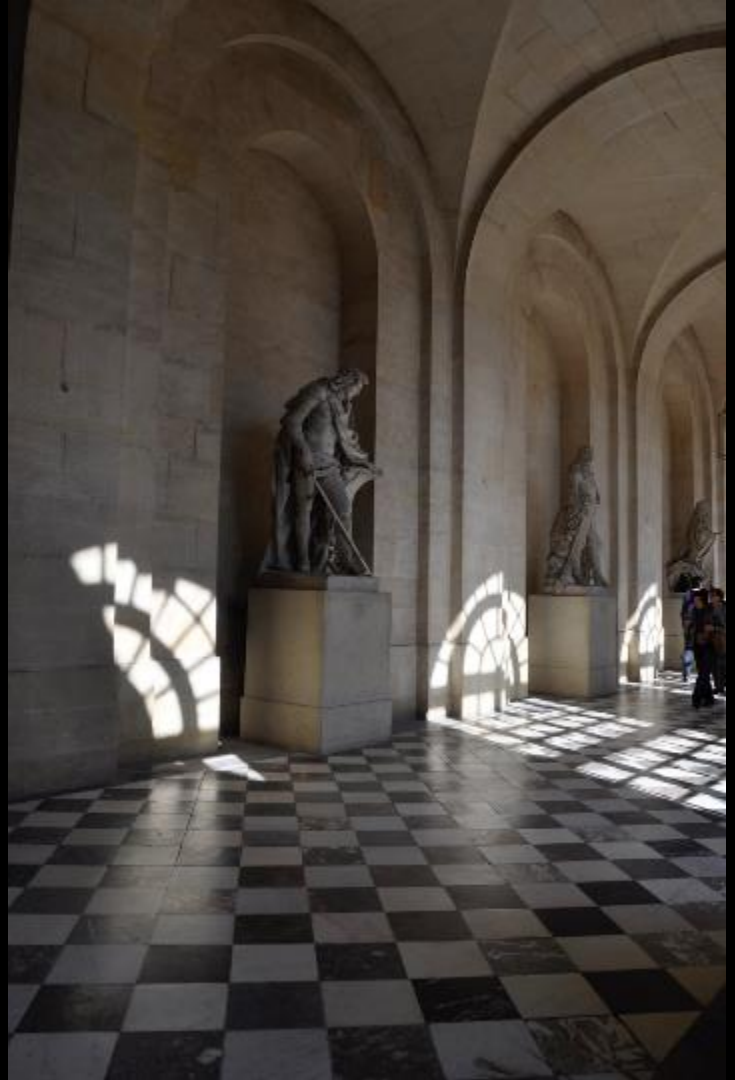
Church of St. Ignatius of Loyola
Rome, Italy
1650

Chateau de Chenonceaux
Chenonceaux, France
Philibert de l'Orme
1559

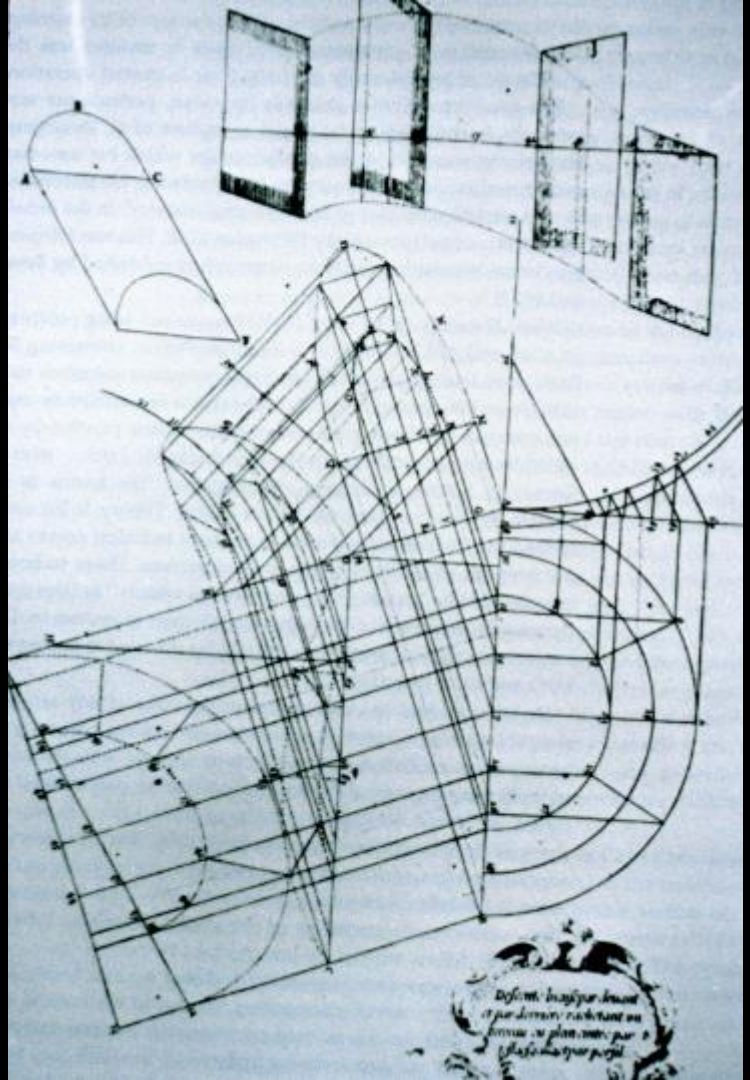


68 Temple of Apollo at Didyma (*c.* 300 B.C. and later): sloping barrel vault above ramp to altar court; perspective view, partly exploded to show shape of vaulting blocks


Palace of Versailles
France
Philibert Le Roy
1631



Stereometry deals with the measurements of volumes of various solids



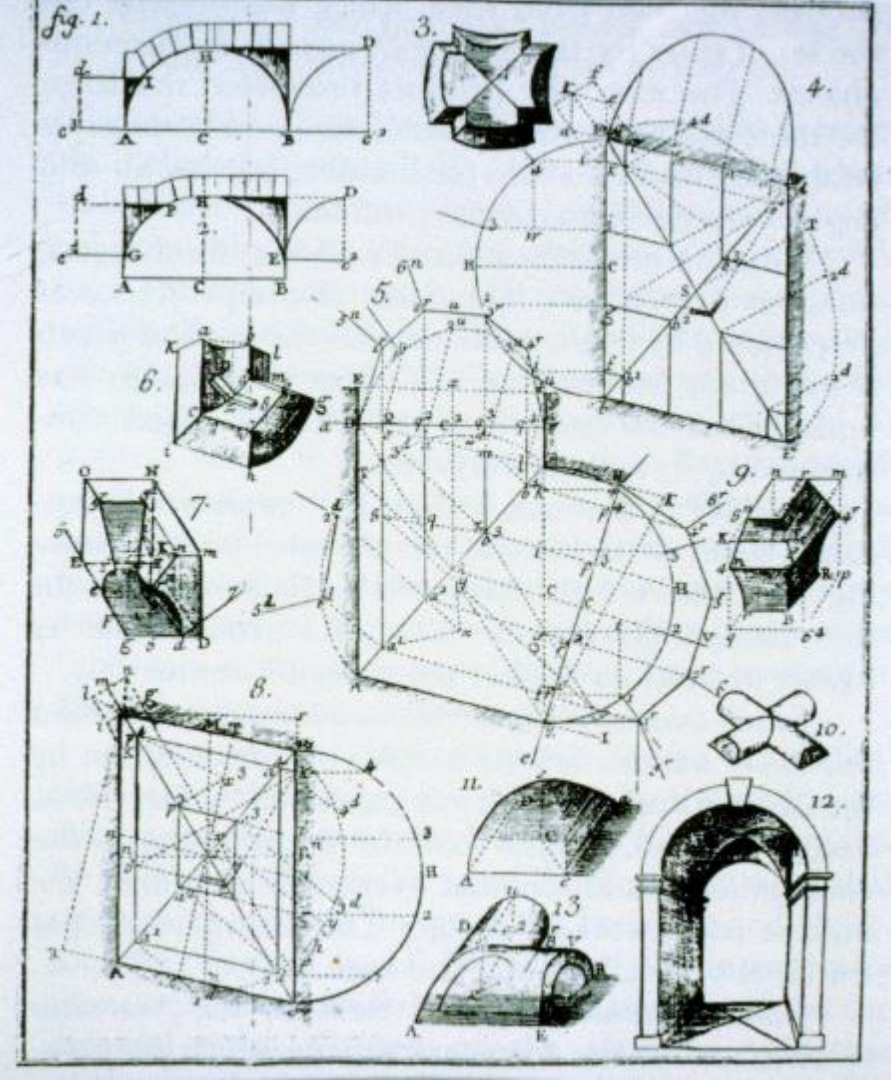


fig. 1.
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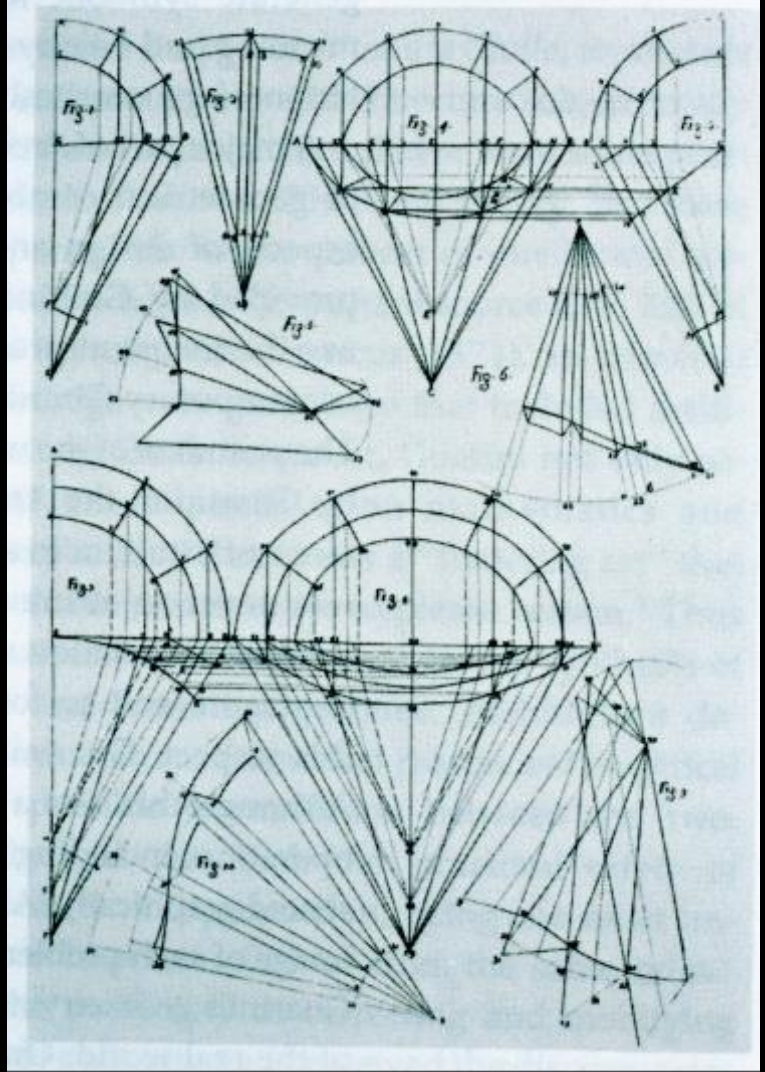


Fig 1
Fig 2
Fig 4
Fig 5
Fig 6
Fig 7
Fig 8
Fig 9
Fig 10

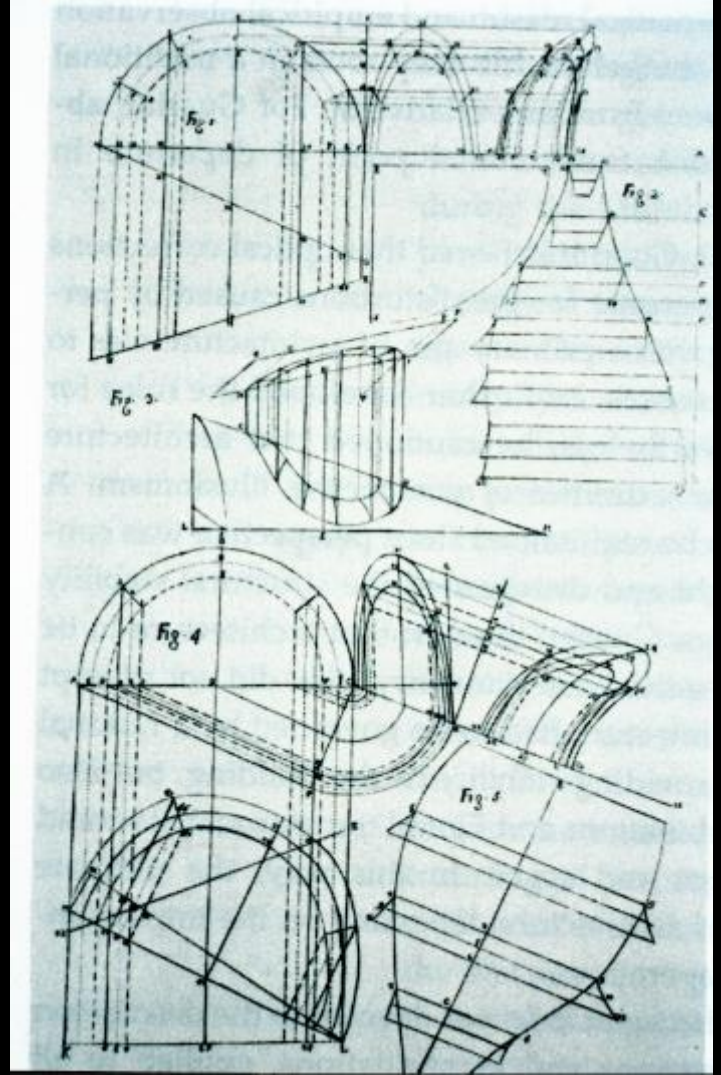
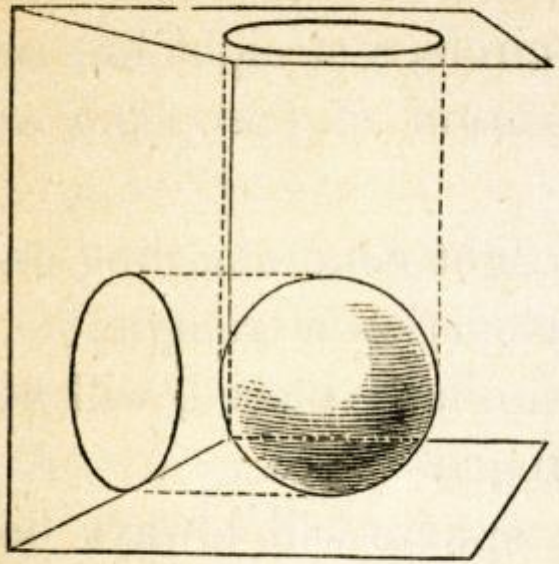


Fig 1
Fig 2
Fig 3
Fig 4
Fig 5

Fig. 34.



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Every plane section of a
acute angle, greater than th
will be an ellipse, or a segm

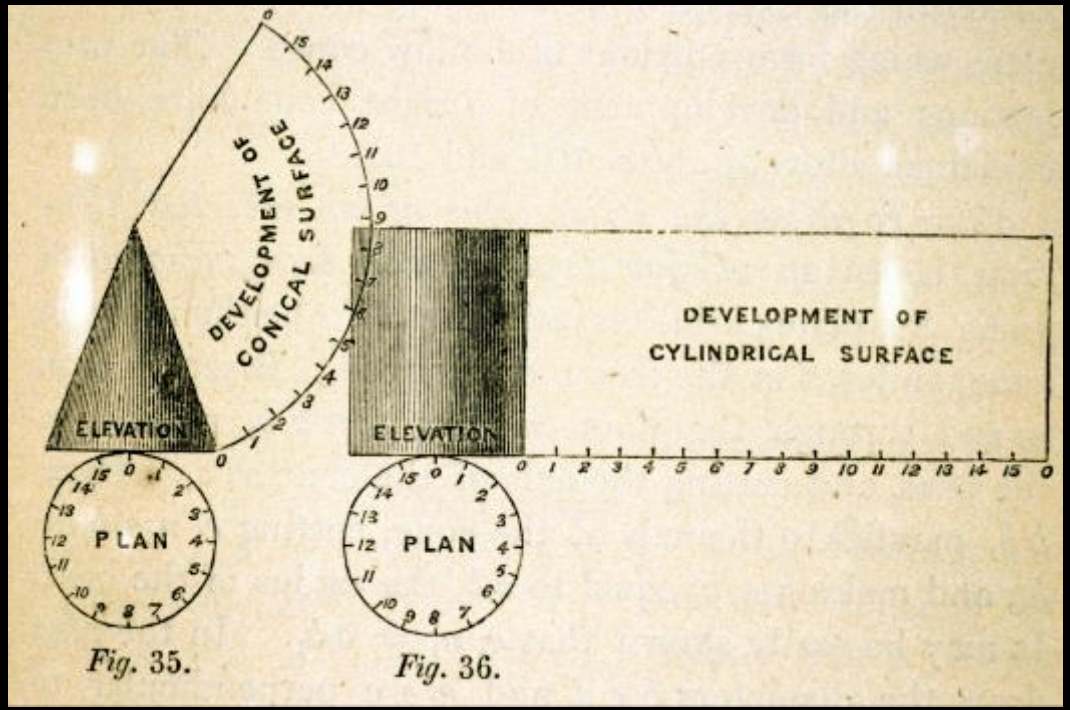
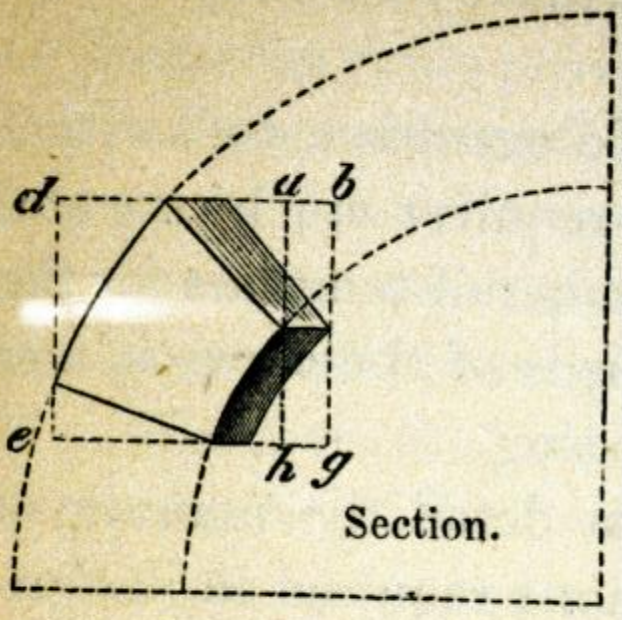
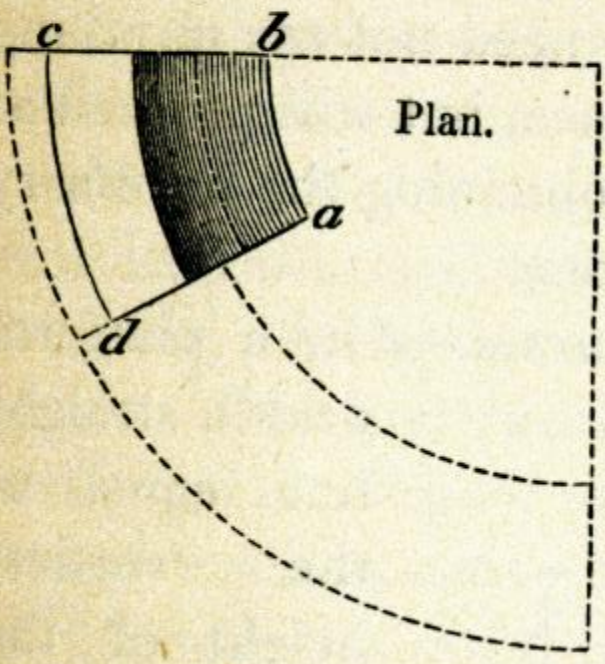


Fig. 35. *Fig.* 36.

Fig. 63.

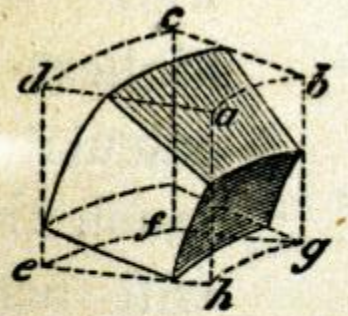


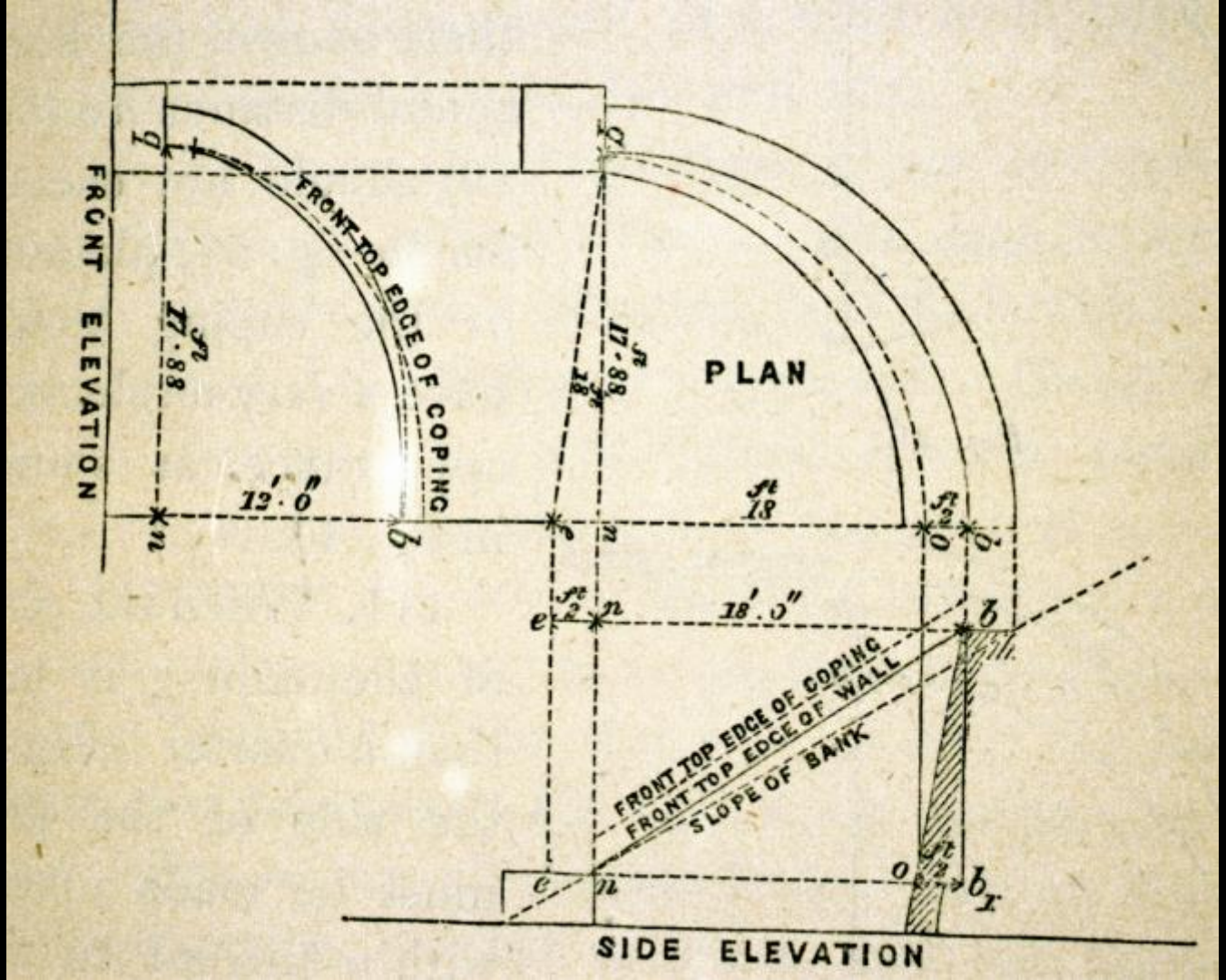
Section.

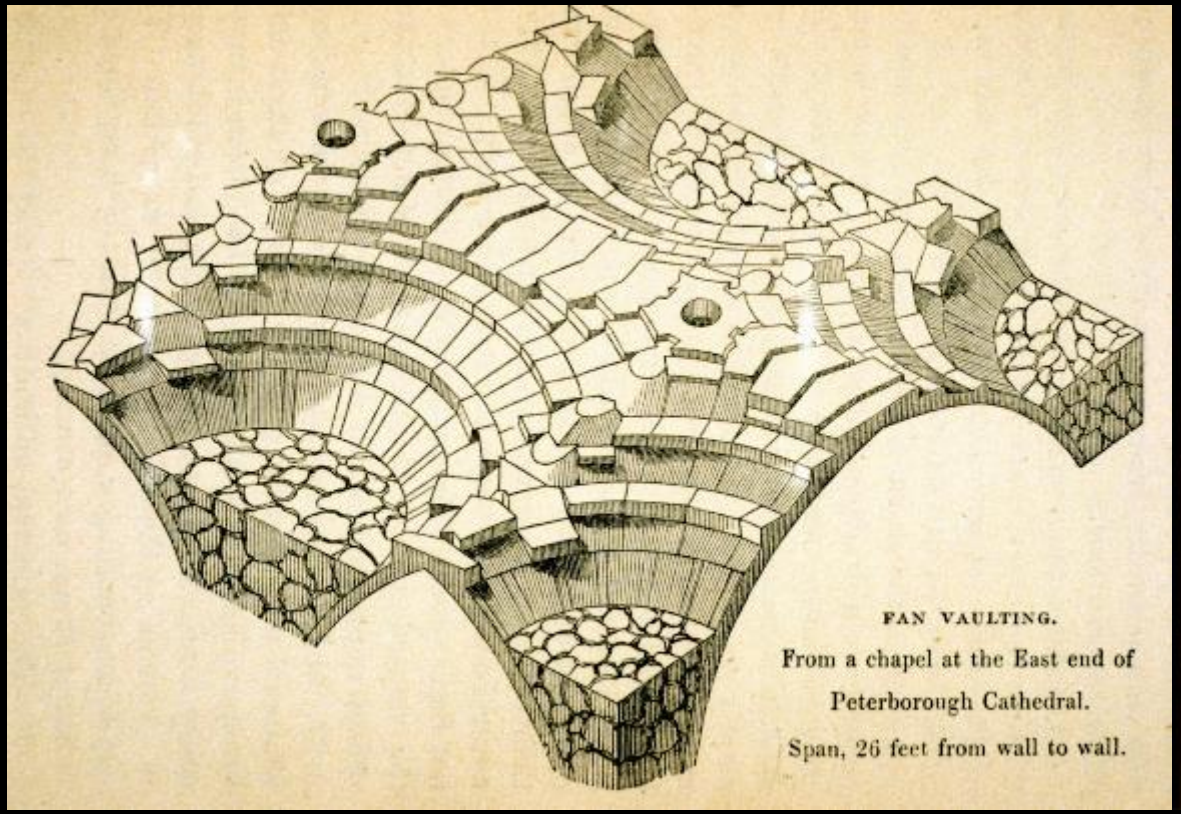


Plan.

Perspective view.




FRONT ELEVATION
FRONT TOP EDGE OF COPING
17'.88
12'. 6"
PLAN
17'.88
18'
18'. 3"
FRONT TOP EDGE OF COPING
FRONT TOP EDGE OF WALL
SLOPE OF BANK
SIDE ELEVATION

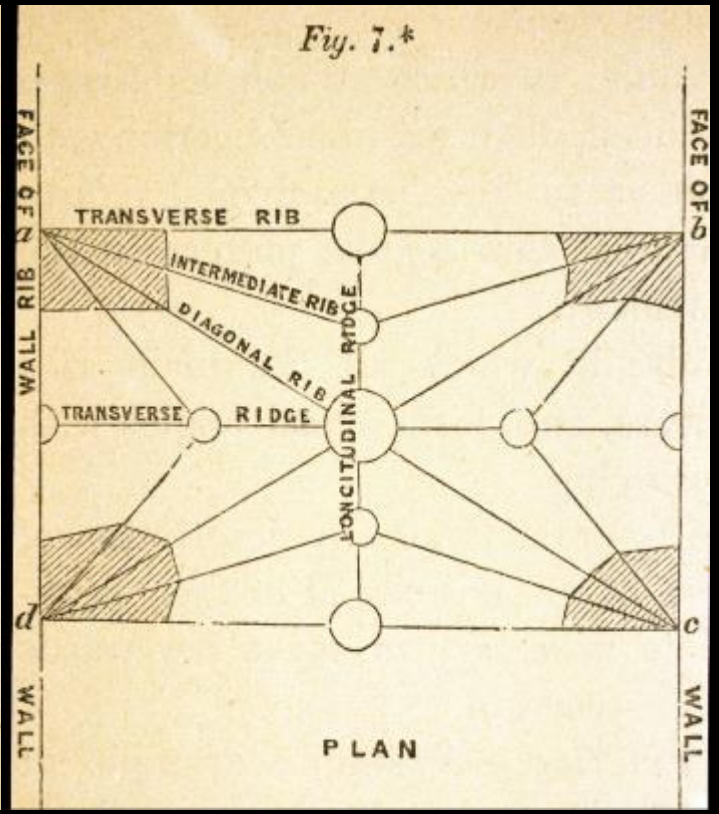


FAN VAULTING.

From a chapel at the East end of Peterborough Cathedral.

Span, 26 feet from wall to wall.

*Fig. 7.**



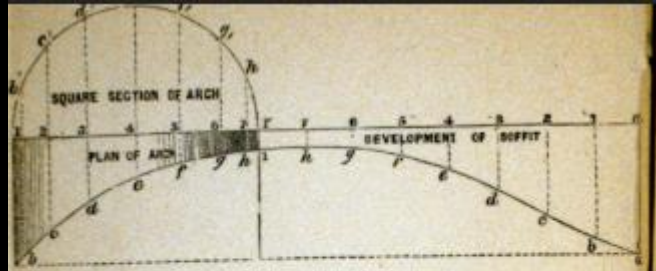


FIG. 44.

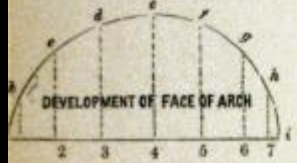
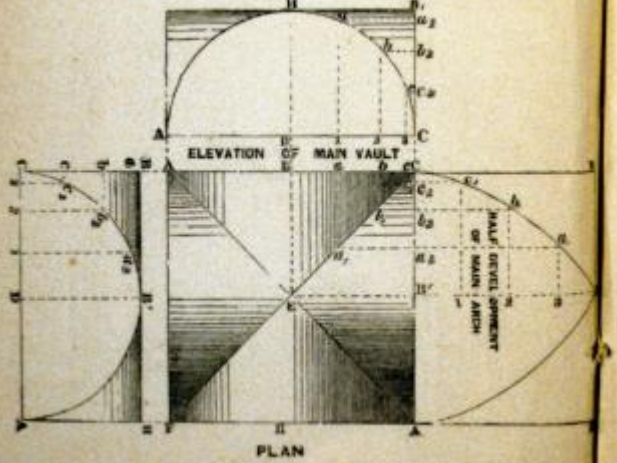


FIG. 45.



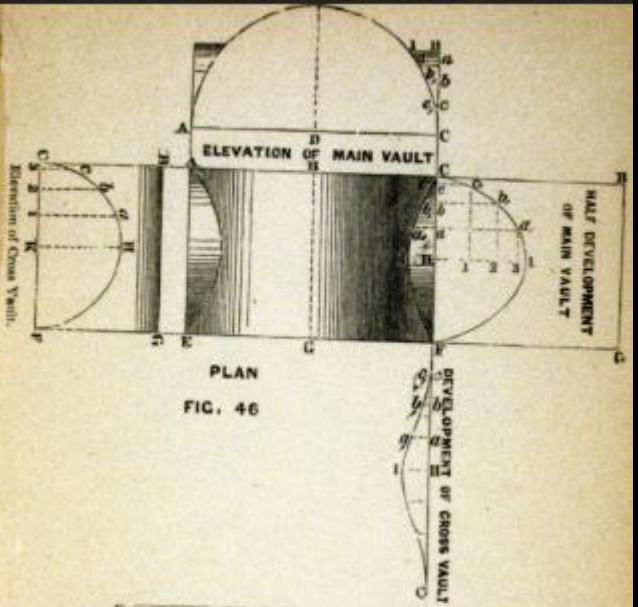


FIG. 46

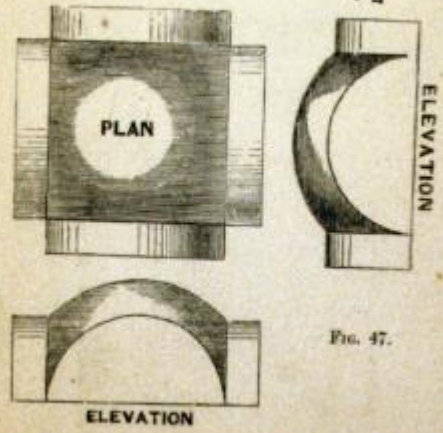


FIG. 47.

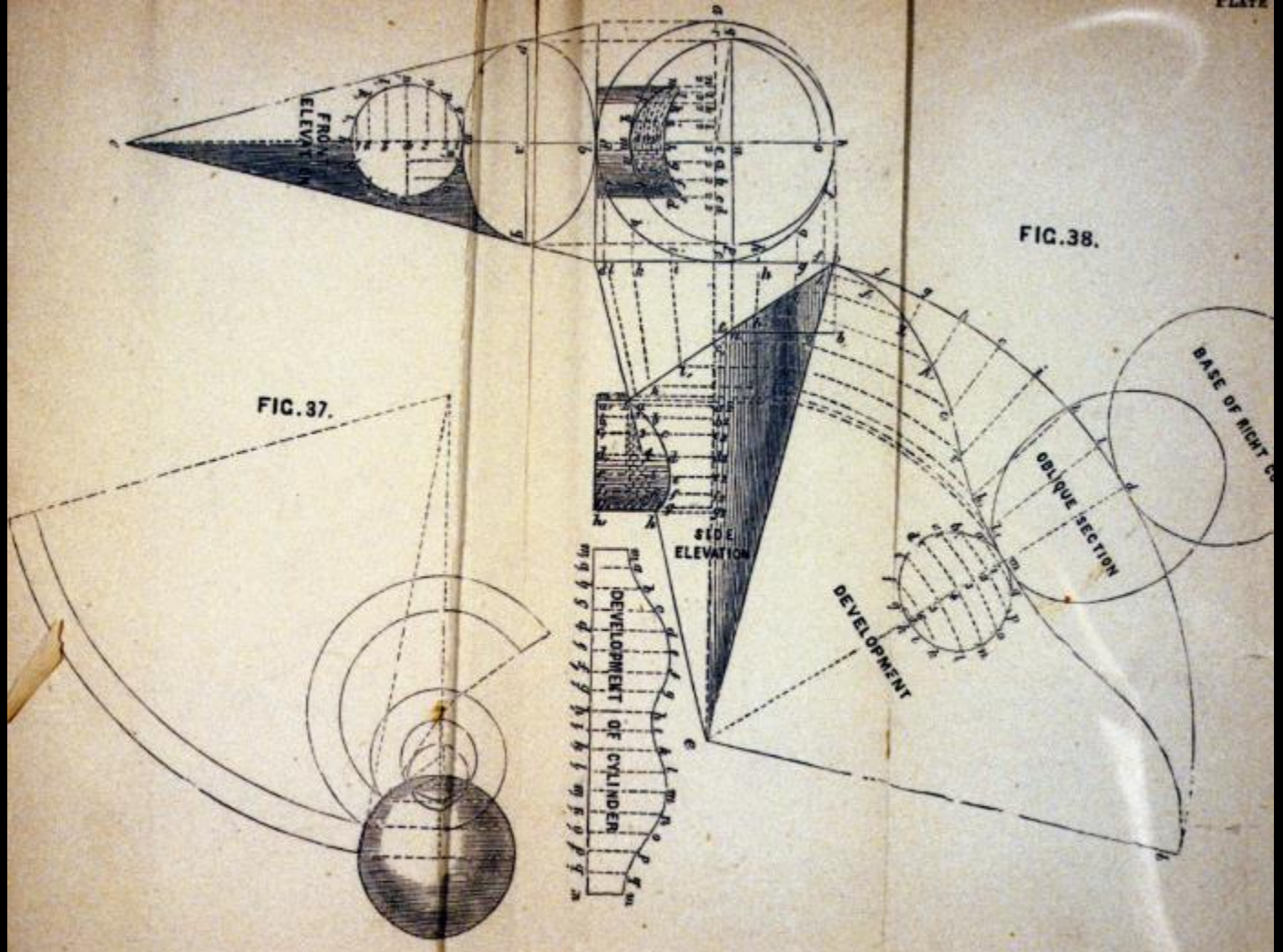
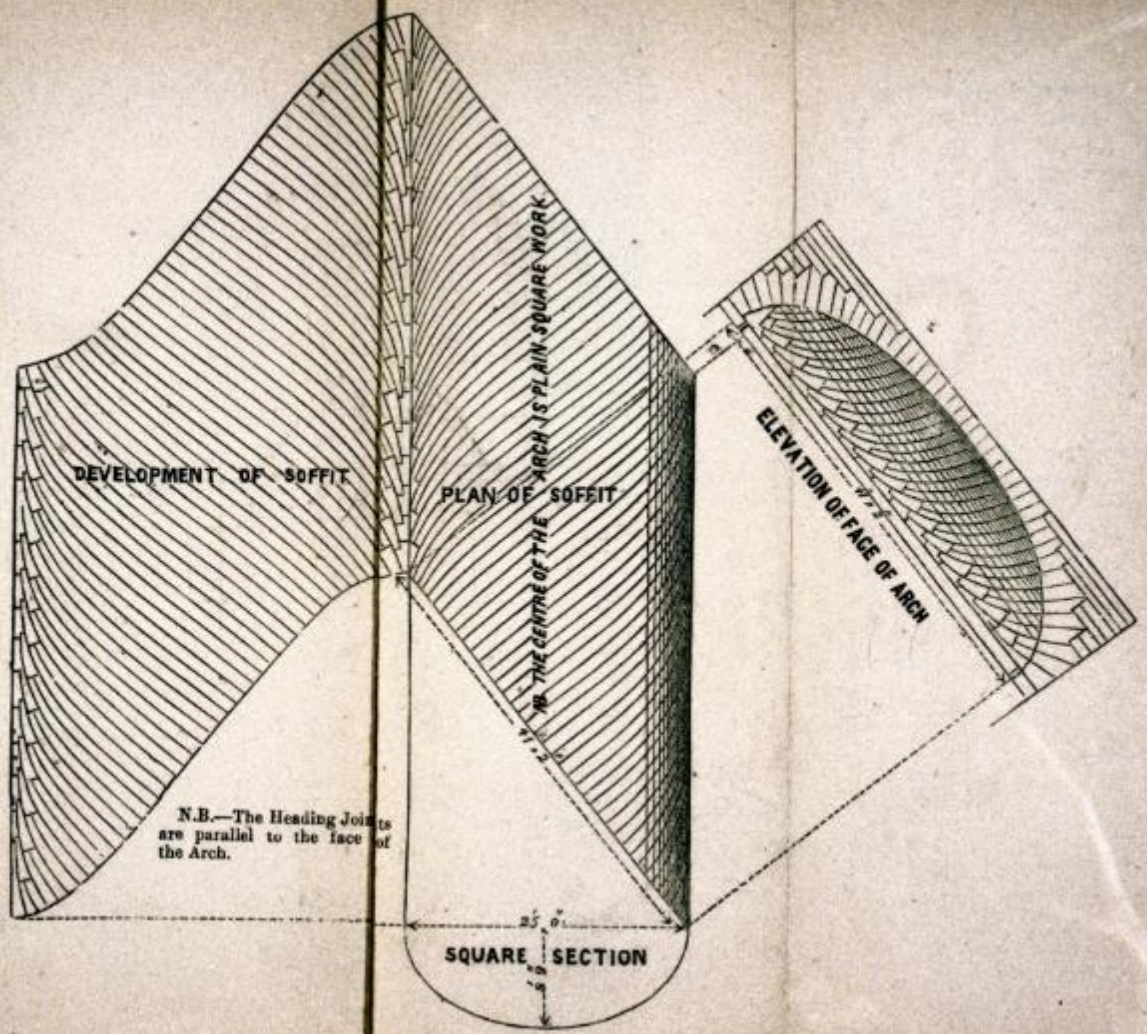
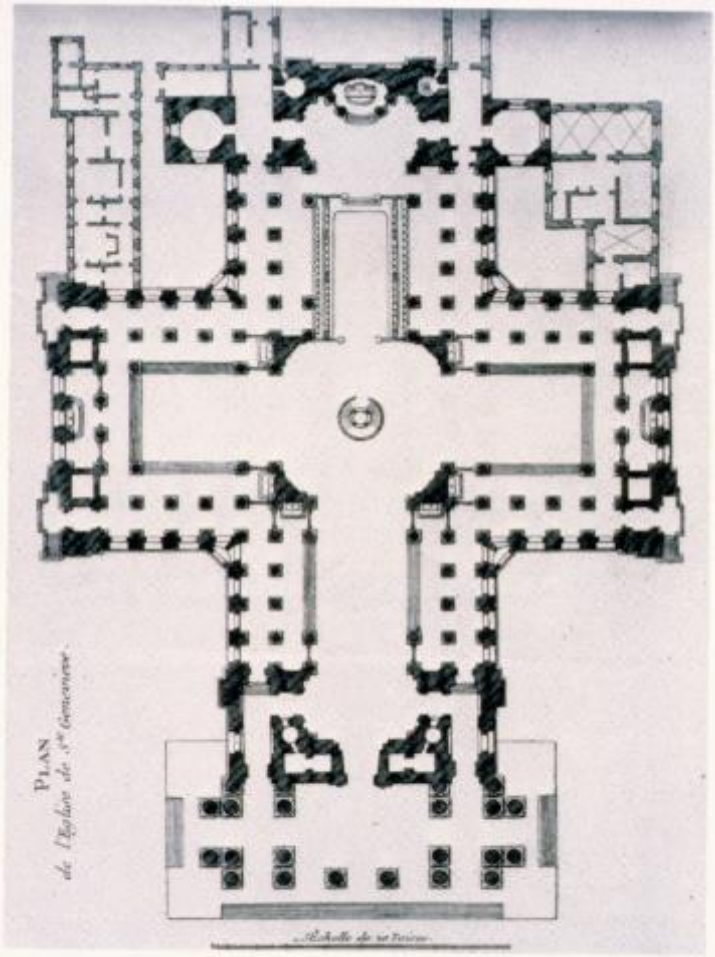

FRONT ELEVATION
PLAN
SIDE ELEVATION
DEVELOPMENT OF CYLINDER
OBLIQUE SECTION
BASE OF RIGHT CO
DEVELOPMENT

FIG. 37.

FIG. 38.


DEVELOPMENT OF SOFFIT
PLAN OF SOFFIT
THE CENTRE OF THE ARCH IS PLAIN SQUARE WORK
ELEVATION OF FACE OF ARCH
N.B.—The Heading Joints are parallel to the face of the Arch.
25' 0"
SQUARE SECTION

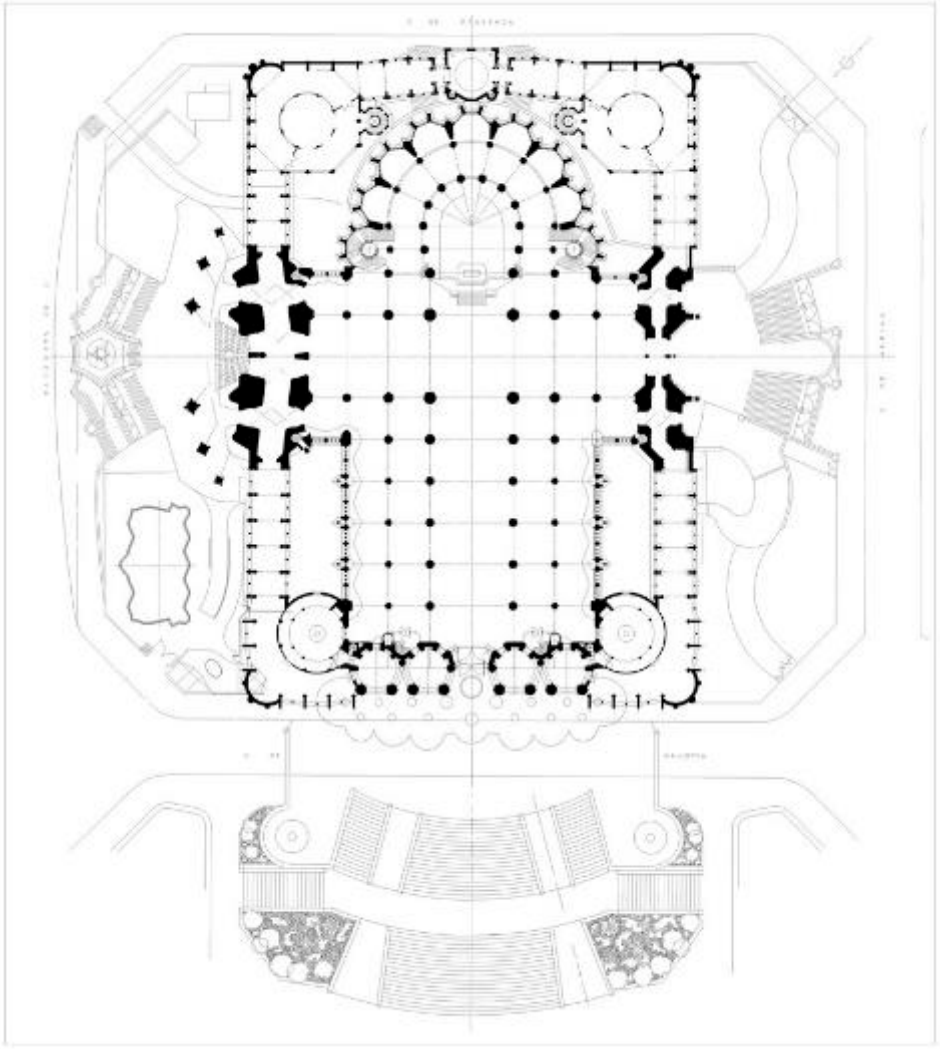
Church of Ste. Genevieve
(Pantheon)
Paris, France
Jacques-Germain Soufflot
Jean-Baptiste Rondelet
1789

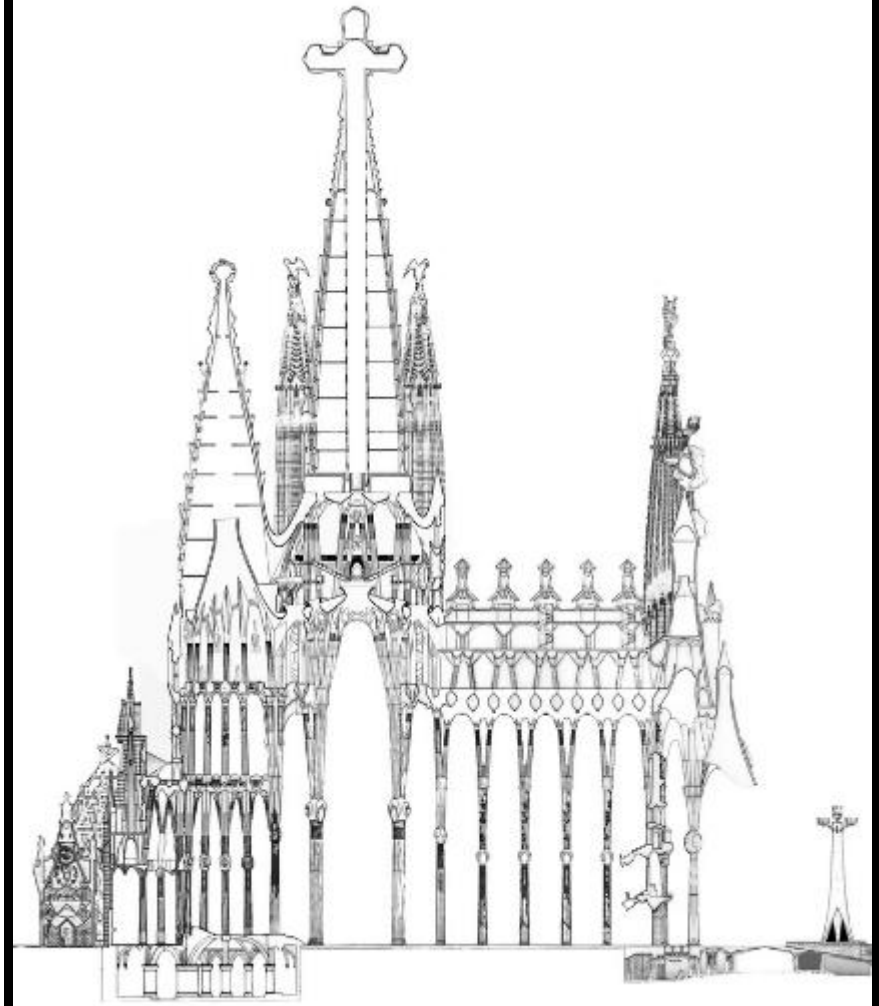


89 The church of Ste-Geneviève, Paris, Soufflot's revised plan (engraving from Piganiol de la Force, 1765). The plan shows the extensions to the nave and choir that Soufflot had introduced about 1758

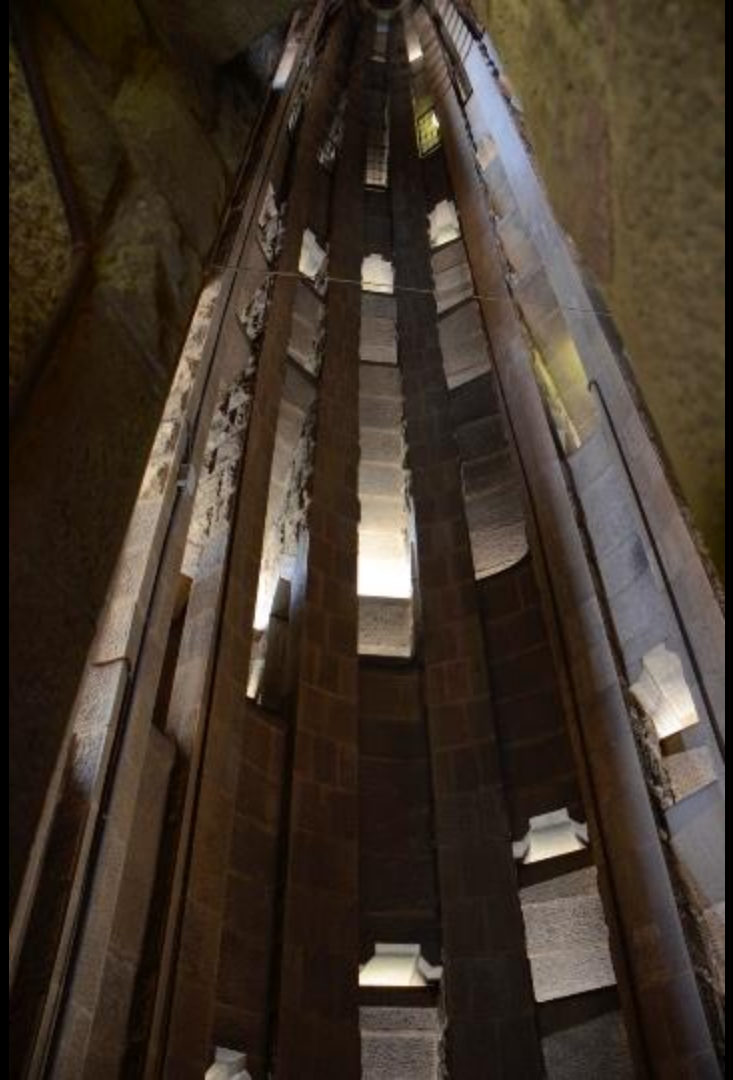

AUX GRANDS HOMMES LA PATRIE RECONNAISSANTE

Church of Sagrada Familia
Barcelona, Spain
Antonio Gaudi
1883 and ongoing








Nikon

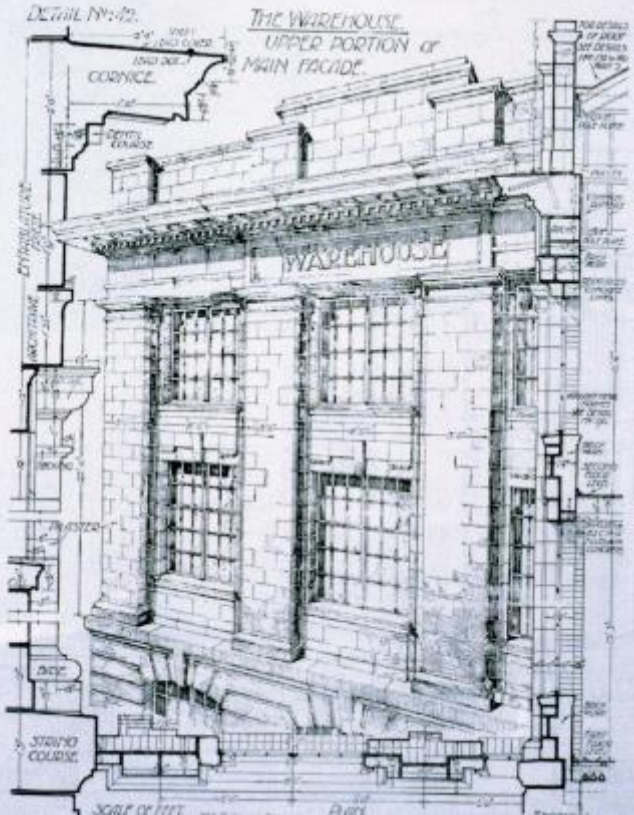
modern stone

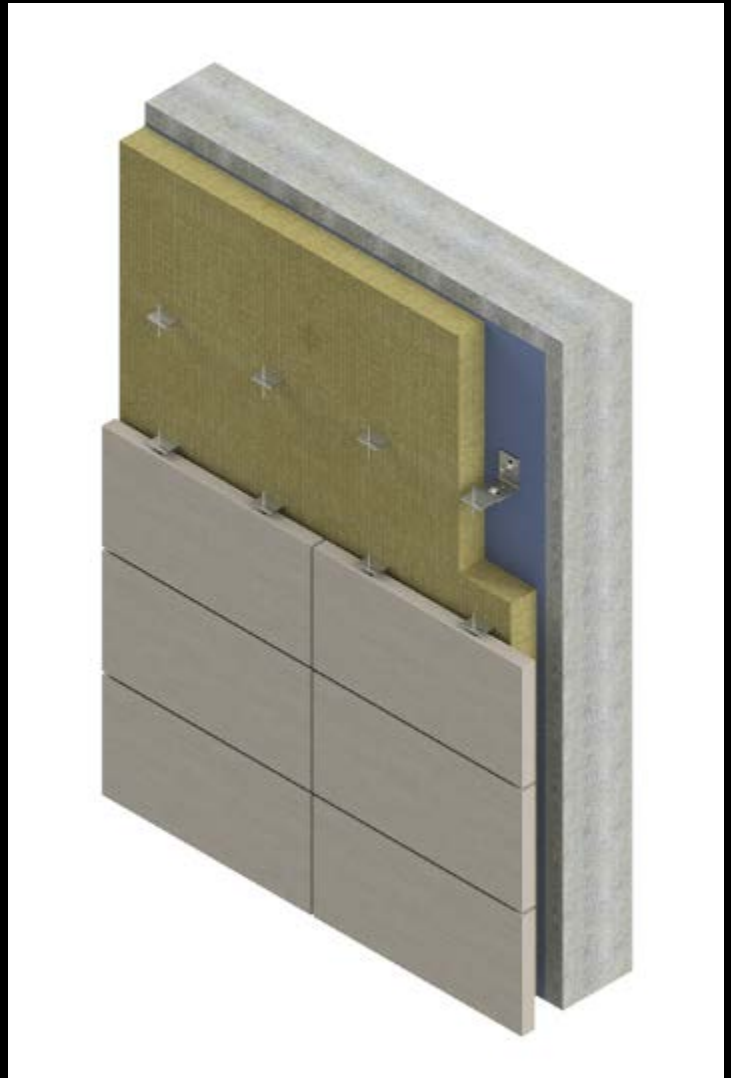
predominantly VENEER applications

Stone in use Detail sheet 11

Stonework drawing

An illustration taken from the AJ of 24 January 192
where Frederick Chatterton points out the merits o
'Architectural building construction' by Messrs W.
Jaggard and F. E. Drury. In Chatterton's words, th
illustration combines authentic practical data with
well designed examples of their application.






Gilbane

Embassy of Canada
Washington, DC, USA
Arthur Erickson
1989

Eglise Ste. Trinite
Ugo Brunoni Architect
Geneve, Switzerland
1999