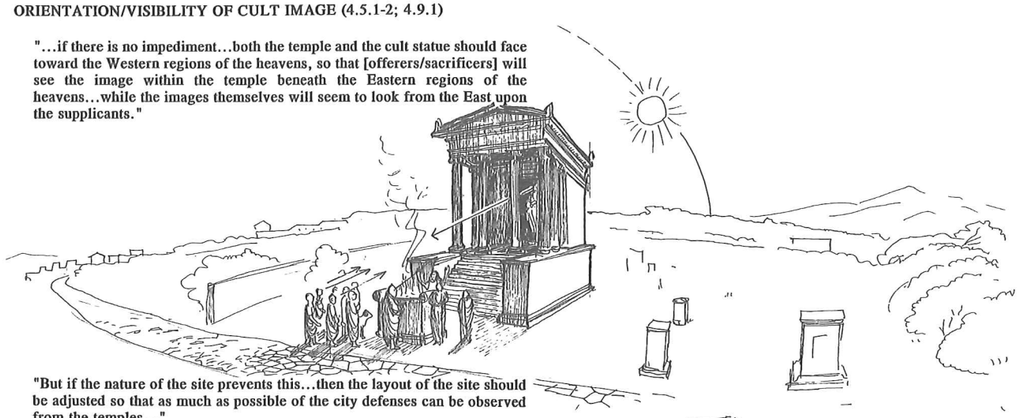
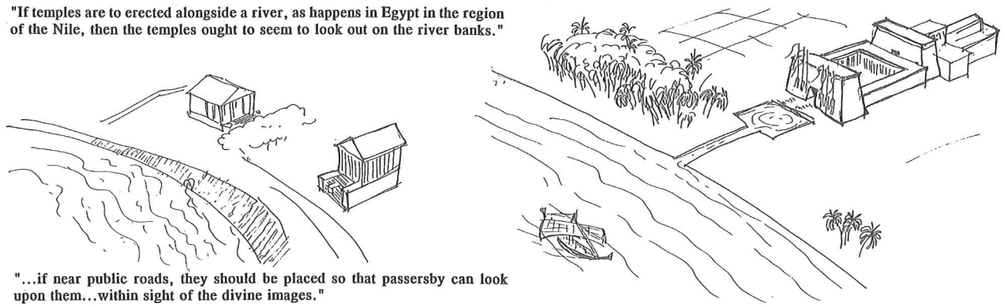
ORIENTATION/VISIBILITY OF CULT IMAGE (4.5.1-2; 4.9.1)

"...if there is no impediment...both the temple and the cult statue should face toward the Western regions of the heavens, so that [offerers/sacrificers] will see the image within the temple beneath the Eastern regions of the heavens...while the images themselves will seem to look from the East upon the supplicants."



"But if the nature of the site prevents this...then the layout of the site should be adjusted so that as much as possible of the city defenses can be observed from the temples..."

"If temples are to erected alongside a river, as happens in Egypt in the region of the Nile, then the temples ought to seem to look out on the river banks."



"...if near public roads, they should be placed so that passersby can look upon them...within sight of the divine images."

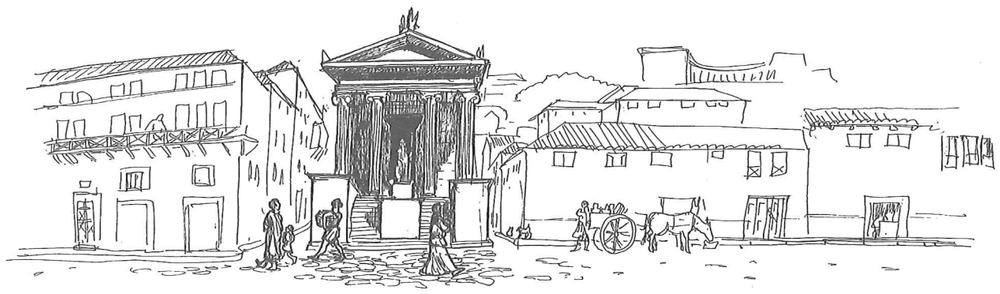


Figure 69. Orientation/Visibility of Cult Image (4.5.1–2; 4.9.1).

THE DORIC DOOR (4.6.1-2)
(THE ATTIC DOOR, 4.6.6)

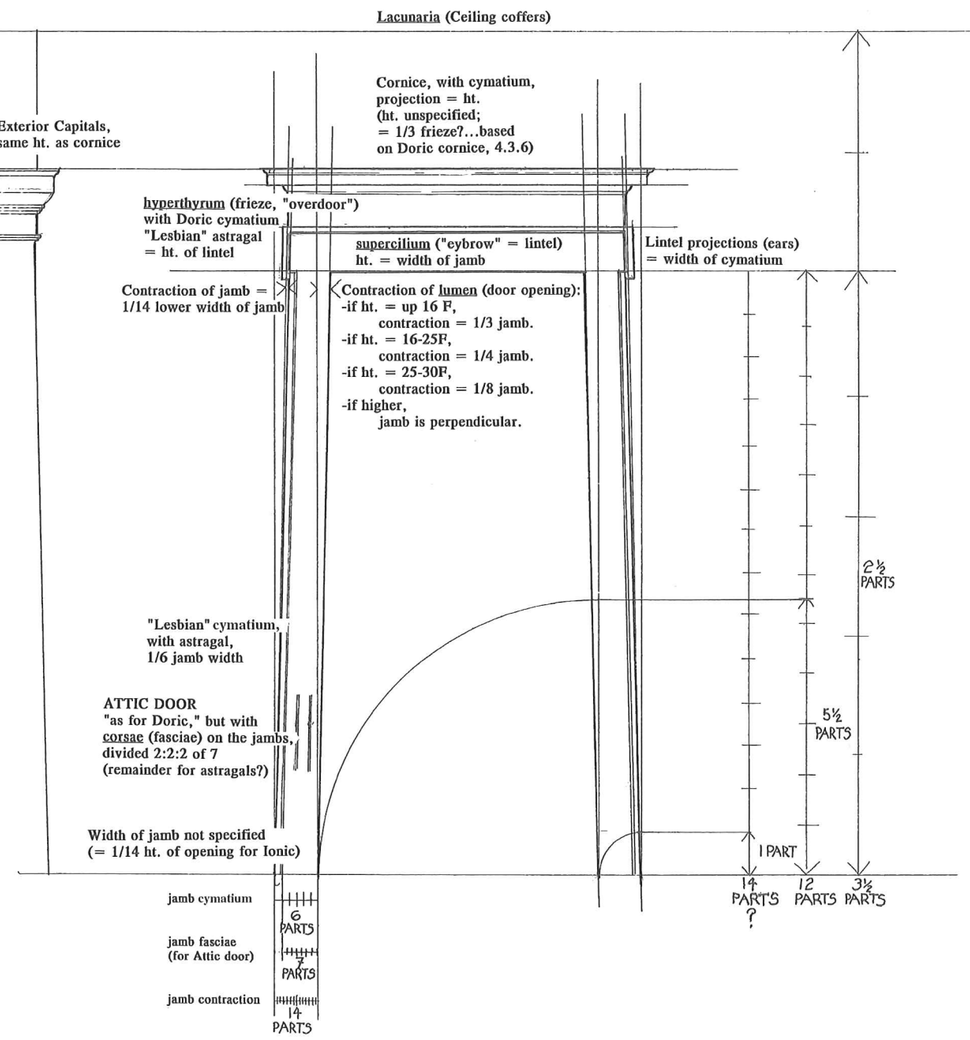


Figure 70. The Doric Door (4.6.1–2); The Attic Door (4.6.6).

THE IONIC DOOR (4.6.3-4)

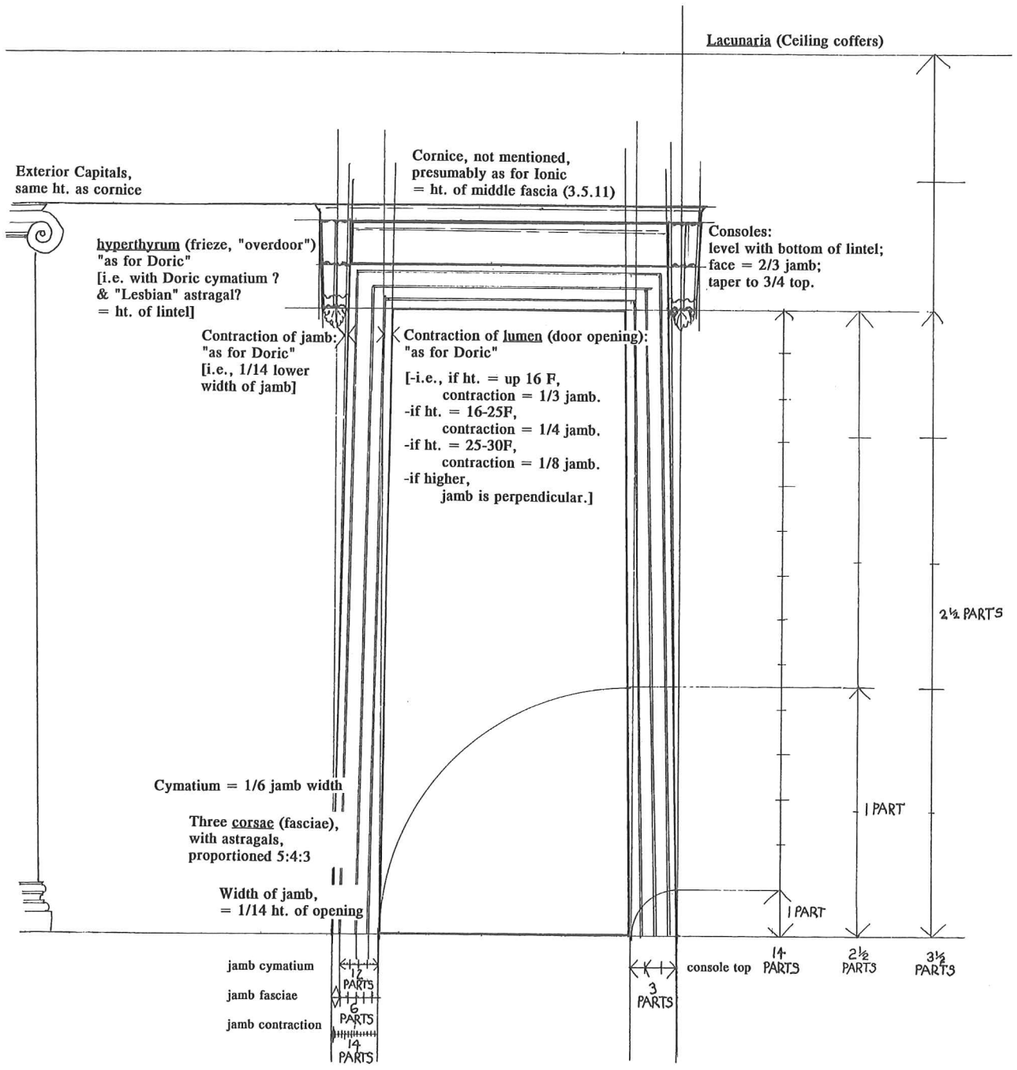


Figure 71. The Ionic Door (4.6.3–4).

DOOR PANELS (4.6.4-5)

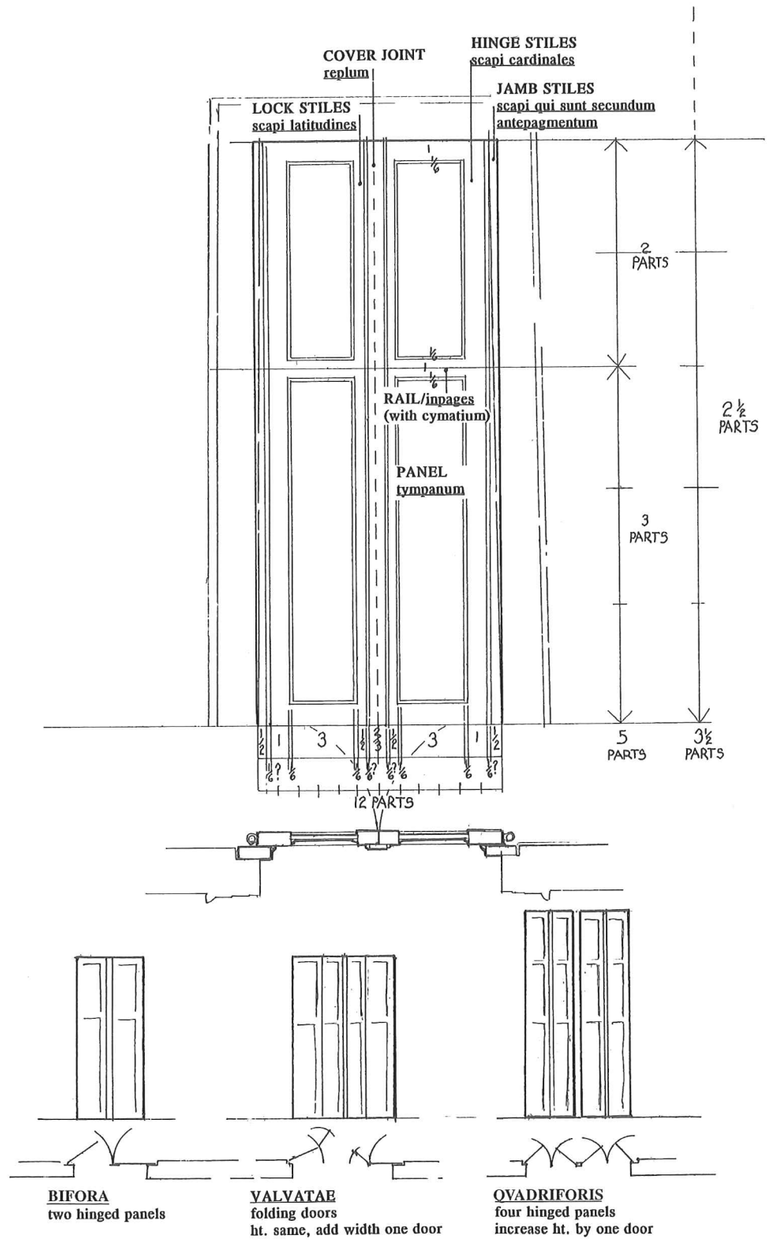


Figure 72. Door Panels (4.6.4–5).

TUSCAN DESIGN/TUSCANICAE DISPOSITIONES (4.7.1-5)

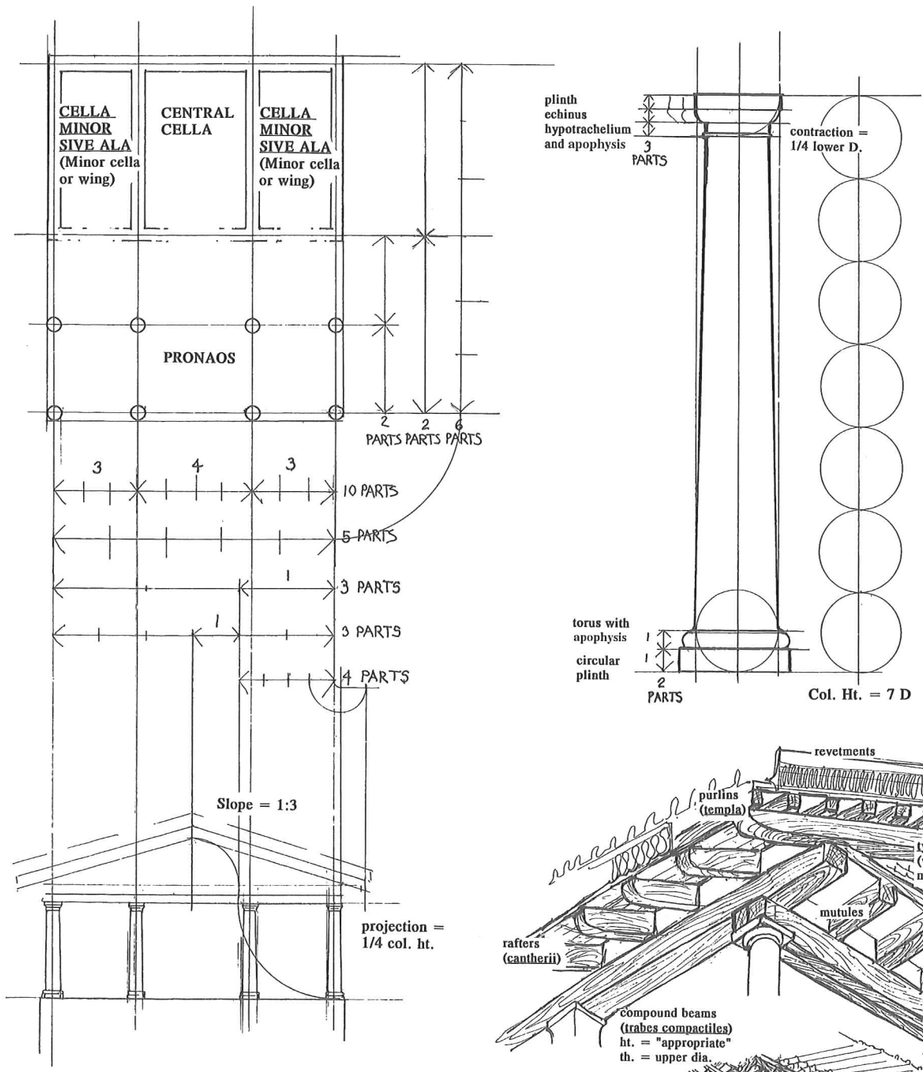


Figure 73. Tuscan Design (*Tuscanicae Dispositiones*) (4.7.1–5).

platform (4.8.1) (Figure 74)

A "tribunal" could be just the floor of the porch, but it implies a speaking platform, hence possibly a platform inserted into a staircase.

other types (4.8.4–7) (Figures 75, 76)

Five times in Book 4 Vitruvius mentions the possibility of creating new architectural forms by analyzing principles and combining elements:

- 4.1.2: Corinthian entablature can be either Doric or Ionic.
- 4.1.3: By the introduction of a third type of capital (Corinthian), a third type of column has developed out of the other two.
- 4.1.12: The existence of other types of capitals, whose names and symmetries he is not able to give, but which seem to have had their vocabulary drawn from Corinthian, Ionic, and Doric.
- 4.2.5: Criticism of placing representations of mutules over dentils, which is the reverse of logical structure (*asseres* over *cantherii*).
- 4.6.4–6: Creating a new type of plan by taking everything that normally is on the front and transferring it to the side (i.e., transverse cella), or transferring Tuscan principles of plan disposition to Corinthian or Ionic buildings.

BOOK 5

poems . . . reading aloud (5.praef.1)

Education and didactic literature relied a great deal on poetry as an aid to memorization (e.g., verse descriptions of astronomy or science, such as Manilius or Lucretius). Most reading, even in libraries, was aloud, or at least mumbled.

the City is thronged (5.praef.3)

This probably refers to the increase of business activity under the Pax Augusta.

Pythagoras . . . [principle of] cubes (5.praef.3)

MSS read 250, Fra Giocondo supplies 216, the cube of six.

custom of giving gladiatorial games in the forum (5.1.1)

This continued down into the end of the Republic. See Commentary 10.praef.3.

parapet (5.1.5)

Pluteus, generally a parapet or screen. Also means a movable screen or protective parapet, or the protective back to a couch.

I myself have designed this type of building . . .
and supervised its construction (5.1.6) (Figures 79, 80)

The phrase *conlocavi curavique* almost certainly means "I designed and supervised it," not just that he was the contractor or construction architect. The primary meanings of *conlocare (collocare)* are to put out, set out, lay out, arrange, determine (i.e., as in a design). Secondary meanings include to station (soldiers), give in marriage, deposit or spend money, or to put out a contract. *Curare* means to tend, administer, have care of.

Colonia Julia Fanestris (5.1.6)

The former Fanum Fortunae, made a colony by Augustus, on the Adriatic coast.

The Basilica at Fano (5.1.6–10) (Figures 79, 80)

It has been suggested that the section of the *Ten Books* on the basilica at Fano was inserted into the manuscript later, perhaps after publication, because it seems to have features that blatantly contradict the prescriptions for basilicas which immediately precede it.[1] Vitruvius says first that the upper columns of basilicas should be three-quarters the height of the lower, then at Fano he makes them eighteen feet over twenty. However, with one emendation of the text (xv for xviii feet) the reconstruction can be made to correspond almost completely with the preceding prescriptions (with the obvious exception that the one large colonnade instead of two stories of columns is an innovation). Also, as suggested in our introduction, this may be Vitrivius's example of how innovations may be introduced into his prescriptions.

spectators . . . wide open pores (5.3.1)

Vena (fissure, vein, pore, cavity) appears in numerous other passages that use the language of chemical analysis (e.g., 8.3.2, referring to springs welling up from within mountains). The condition of veins serves for Vitruvius as one of the major determinants of what we term chemical bonding because how one material's bond with another may be determined by whether its "pores" are already densely filled with another substance or whether they are open.

Do not mix access to the upper parts
of the theater with that to the lower (5.3.5)

The theater of Marcellus, dedicated in 17 B.C., does as Vitruvius recommends, and this practice becomes standard in Imperial period theaters and amphitheaters. Spectators in cheaper seats were thereby segregated from wealthier theatergoers, and quick access made easy.

voice is a flowing breath of air . . .
endless formation of circles (5.3.6)

This analysis is related to the "antiperistasis" theory of impelled motion (cf. 1.6.2), and stands in contrast to the theory of radial projection of rays (9.1.13).

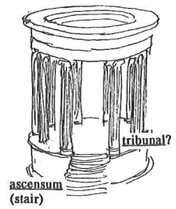
Harmonics (5.4.1–9) (Figure 81)

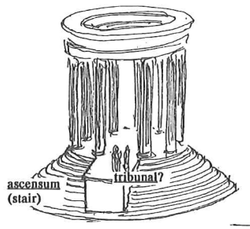
Vitruvius is obviously conversant with Greek musical theory, especially Aristoxenus, and he depends heavily on musical theory for terms such as *genus* (type), *dispositio* (disposition-design),

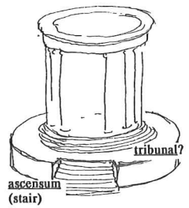
1 F. Pellati, "La basilica di Fano e la formazione del trattato di Vitruvio," *Rendiconti della Pontificia Accademia* 33–34 (1947–49), 153–174.

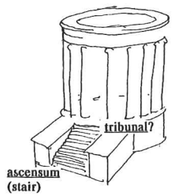
ROUND TEMPLES (4.8.1-3)

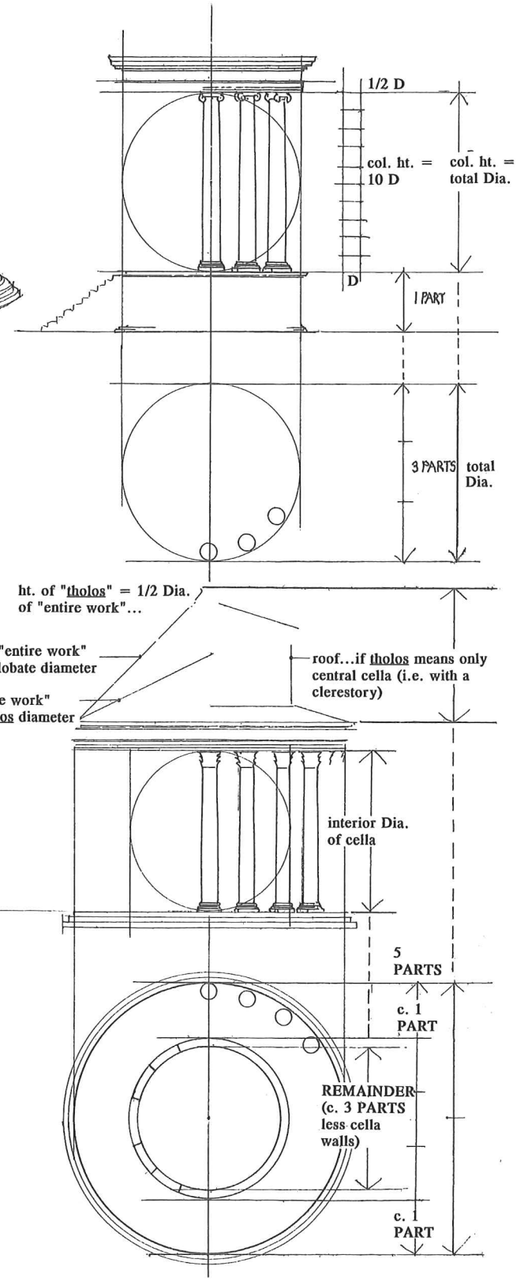
MONOPTERAL



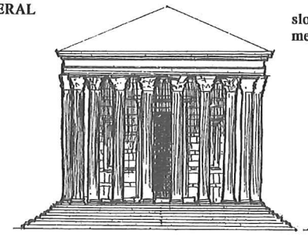


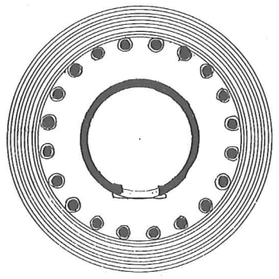






PERIPTERAL





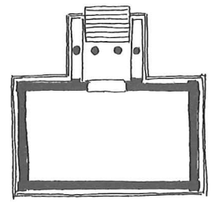
Rome, Round Temple by the Tiber, (Hercules Olivarius?) c. 100 B.C.
[after F. Rakob, Der Rundtempel am Tiber (Mainz, 1973), Beil. 23.]

Figure 74. Round Temples (4.8.1–3).

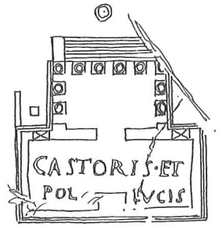
HYBRID TEMPLES AND NEW TYPES (4.8.4)

LATERAL TEMPLES:
"Proportions are all the same...a length equal to double their width...
...everything that is usually in the front has been transferred to the sides."

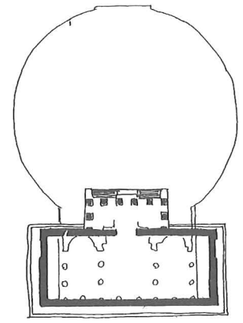
Temple of Veiovis "Between the Two Groves," (next to the Tabularium)
[after A.M. Colini, BollComm (1942), 5seq.)



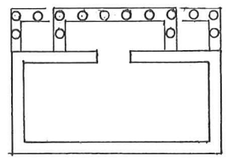
Temple of Castor in the Circus Flaminius
[after M. Conticello de'Spagnolis, Il tempio dei Dioscuri nel Circo Flaminio (Rome, 1984), 43, 59.]



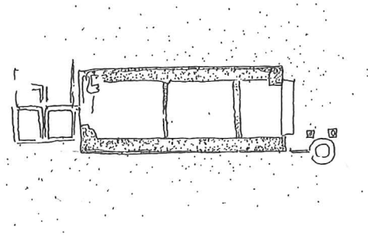
Agrippa's Pantheon
(Hadrianic Pantheon in outline)
[after H. Kähler, Der römische Tempel (Berlin, 1970), fig. 9.]



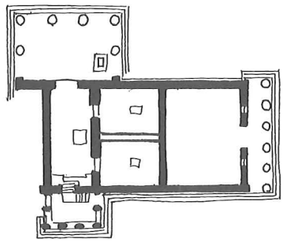
Temple of Diana Nemorensis (Diana at Nemi):
hypothetical reconstruction,
"...where columns have been added to the right and left along the sides of the pronaos."



...from the remains at Nemi:



The temple on the Acropolis at Athens (i.e., the Erechtheion)



Minerva (i.e. Athena) at Sounion
(after W.B. Dinsmoor Jr.)

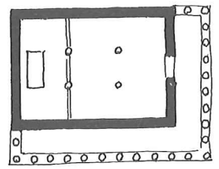


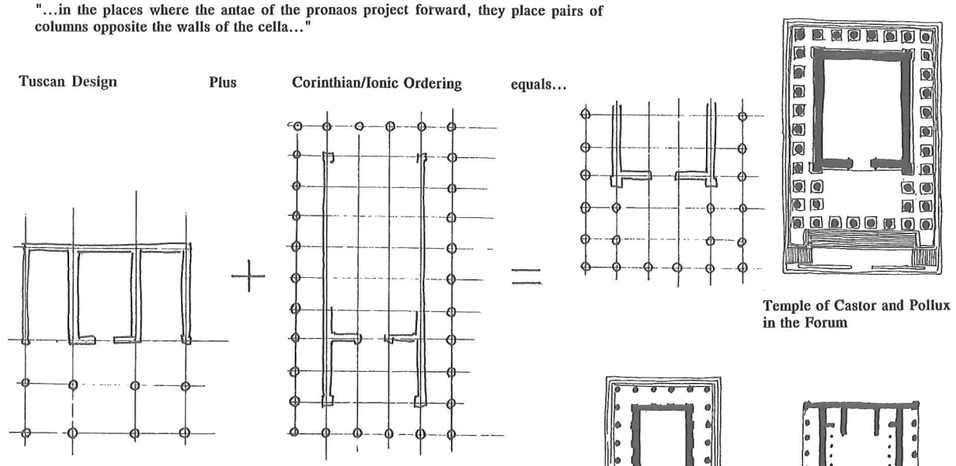
Figure 75. Hybrid Temples and New Types (4.8.4).

HYBRID TEMPLES AND NEW TYPES (4.8.4)

TUSCAN DESIGN APPLIED TO CORINTHIAN/IONIC ORDERING

"...in the places where the antae of the pronaos project forward, they place pairs of columns opposite the walls of the cella..."

Tuscan Design Plus Corinthian/Ionic Ordering equals...



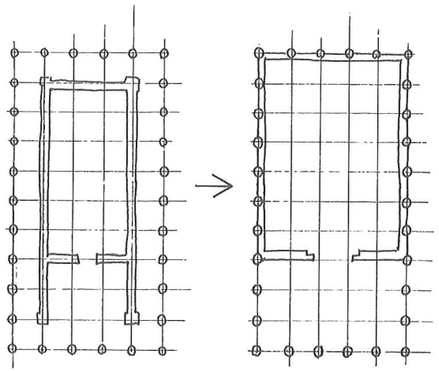
Temple of Castor and Pollux in the Forum

Forum Holitorium Temple (after Palladio)

Tivoli, Hercules Victor

PSEUDOPERIPTEROS (False Peripteros):

Removing the walls of the temple...to the intercolumniations...to create a spacious interior...



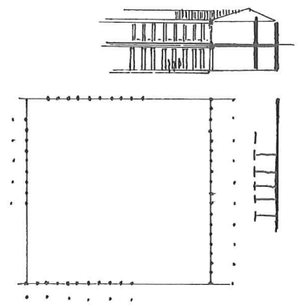
Nîmes, Maison Carrée

Temple of Apollo Palatinus

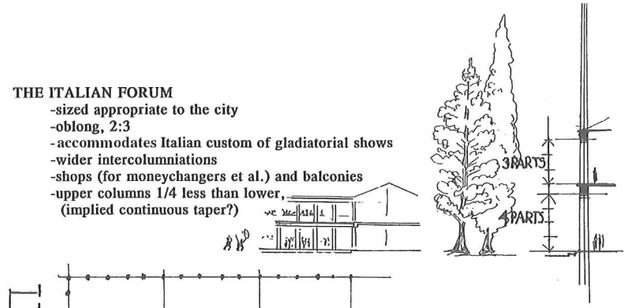
Figure 76. Hybrid Temples and New Types (4.8.4).

THE FORUM (5.1.1-3)

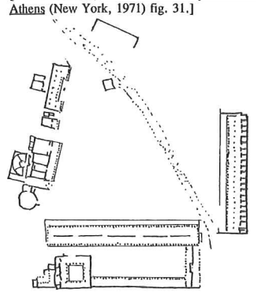
THE GREEK FORUM (i.e. Agora)
- -laid out on the square
- -"double" colonnades, with ambulatories above
- -narrow intercolumniations



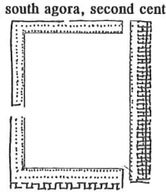
THE ITALIAN FORUM
- -sized appropriate to the city
- -oblong, 2:3
- -accommodates Italian custom of gladiatorial shows
- -wider intercolumniations
- -shops (for moneychangers et al.) and balconies
- -upper columns 1/4 less than lower, (implied continuous taper?)



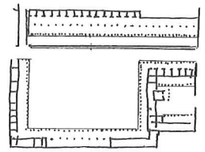
Athens, Agora, as in the mid-second cent. B.C.
[after J. Travlos, Pictorial Dictionary of Ancient Athens (New York, 1971) fig. 31.]



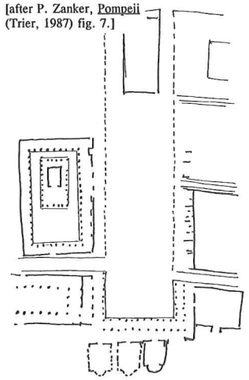
Miletos, south agora, second cent. B.C.



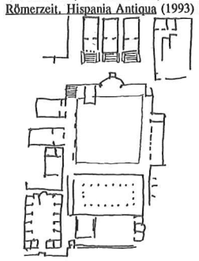
Priene, Agora, after 340 B.C.



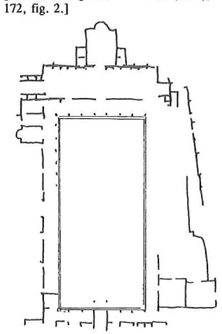
Pompeii, Forum, as in c. 89 B.C.
[after P. Zanker, Pompeii (Trier, 1987) fig. 7.]



Baelo (Spain), Forum, mainly first cent. A.D.
W. Trillmich, Th. Hauschild, Denkmäler der Römerzeit. Hispania Antiqua (1993) fig. 137.]



Iuvanum, mainly first cent. B.C.
[after A. Pellegrino, ArchCl 36 (1984), 172, fig. 2.]



Verona, refounded late first cent. B.C.
[after J.B. Ward Perkins, Cities of Ancient Greece and Italy: Planning in Classical Antiquity (New York, 1974) fig. 59]

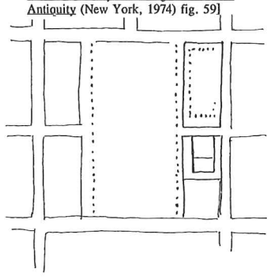


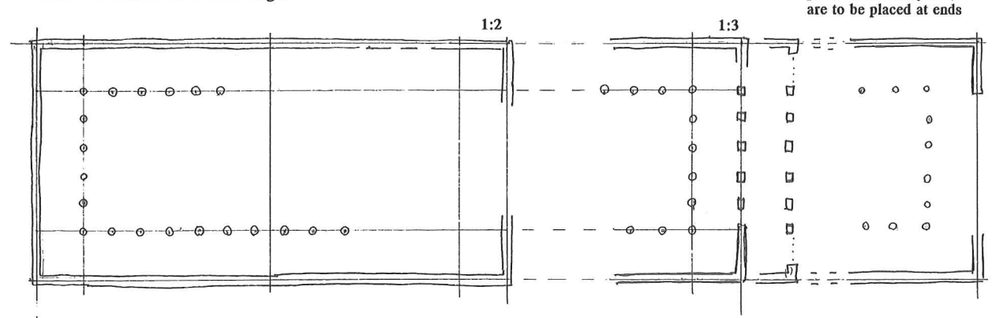
Figure 77. The Forum (5.1.1–3).

THE BASILICA (5.1.4-5)

-site in the warmest location, in order to be able to conduct business in winter

-width of the site, unless nature of the site prevents it, should be between 1/3 and 1/2 length

-if longer, "Chalcidian" porches (presumably open porticos or courtyards) are to be placed at ends



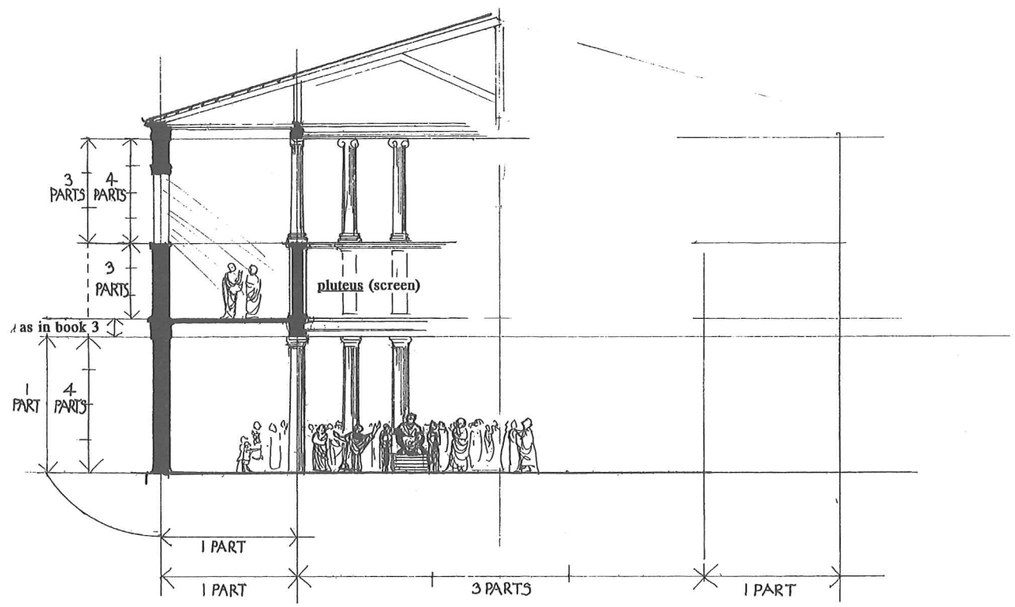
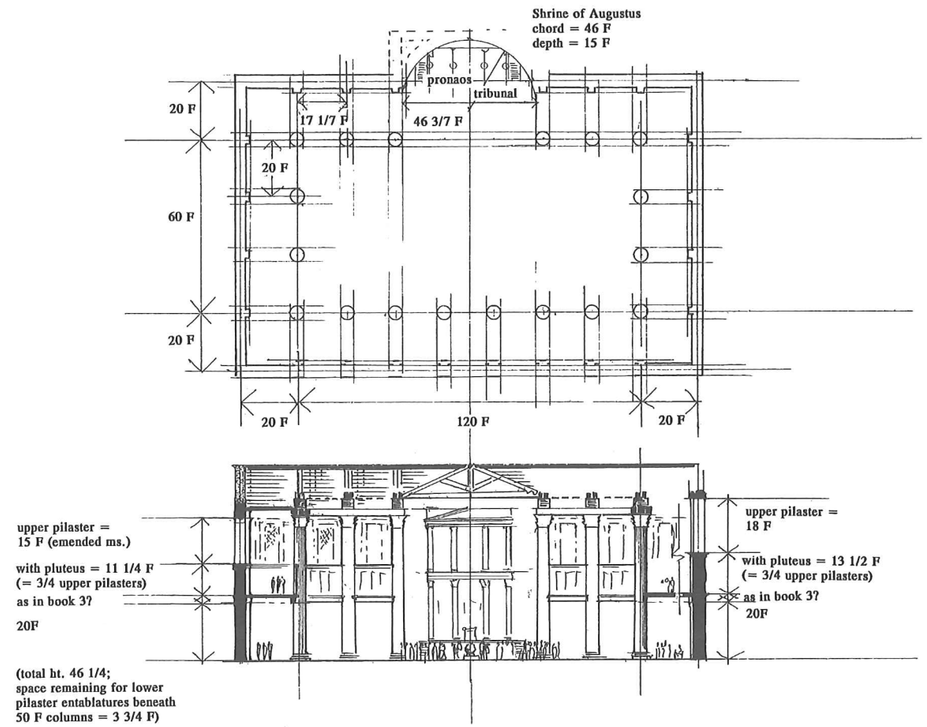
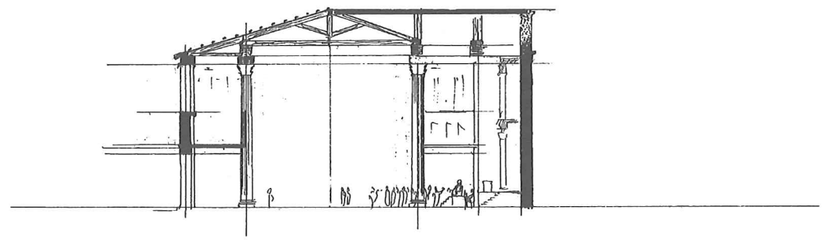


Figure 78. The Basilica (5.1.4–5).

THE BASILICA AT COLONIA JULIA FANESTRIS (FANO)(5.1.6-10)
Drawn with on-center dimensions





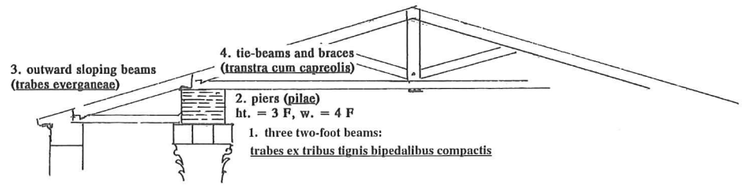


Figure 79. The Basilica at Colonia Julia Fanestris (Fano) (1.6.1–10).

THE BASILICA AT COLONIA JULIA FANESTRIS (FANO)(5.1.6-10)

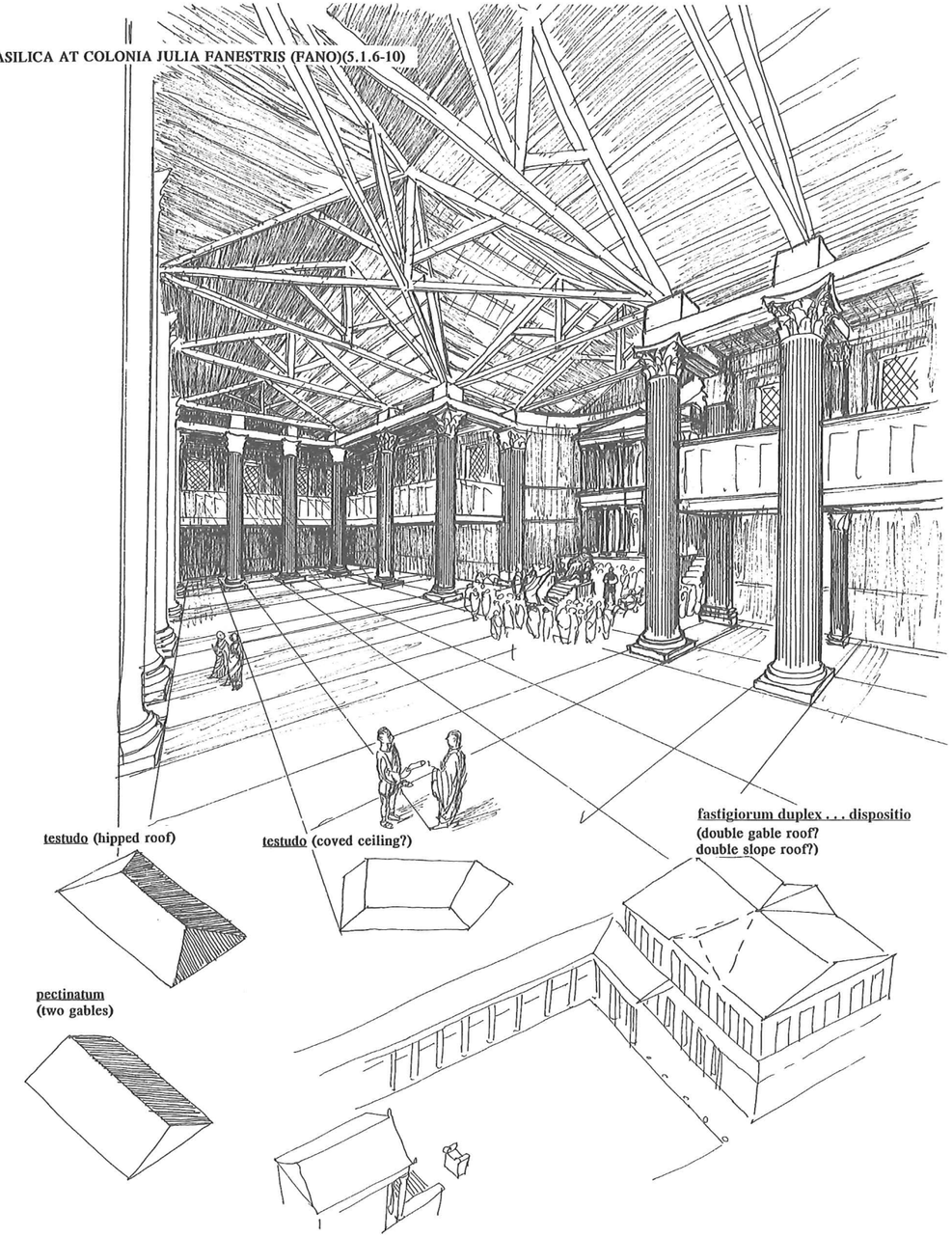


Figure 80. The Basilica at Colonia Julia Fanestris (Fano) (5.6.1–10).

HARMONIC PRINCIPLES: THE SCALES (5.4.1-9)

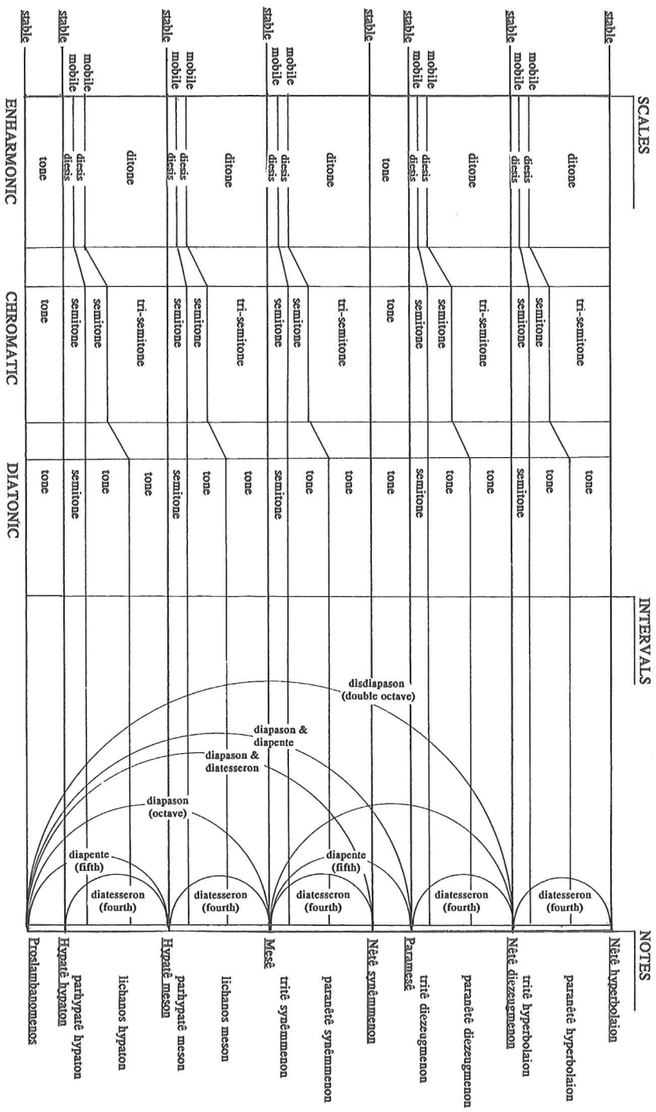


Figure 81. Harmonic Principles: The Scales (5.4.1–9).

pyknon (closely spaced, as in pycnostyle spacing of columns), and certain aspects of the term *eurythmia*. He is also probably dependent on musical theory for awareness of much more sophisticated concepts, such as the difference between empirical measurement and abstract principles (i.e., the phenomenal and the noetic),[2] this awareness informs his constant opinion throughout the *Ten Books* that design by *symmetria* and other rules must almost always be modified for practical, optical, or aesthetic considerations.

This section in effect introduces Vitruvius's readers to the intervals of the three principal *genera* of harmony: enharmonic, chromatic, and diatonic.

Greek musical theory makes a strong distinction between intervals that were *symphona* (concordant, those which blend together) and those that were *diaphona* (discordant).[3] The concordant intervals were the octave, fifth, and fourth, and all those compounded from them; all others were discordant. The concordant intervals were those that were treated as fixed in the musical scales.

Scales were built on tetrachords, that is, intervals of a fourth. Two tetrachords could either be "conjunct" when they shared a tone (i.e., the top note of one was the bottom note of the other) or "disjunct" (when they did not share a note and there was an interval of a tone between them). An octave consisted of two disjunct tetrachords (each usually divided into three smaller intervals by four notes), which amounted to the same thing as a fourth and a fifth (the latter divided into four intervals by five notes).

A tetrachord was an interval of two and a half tones. The two outer notes were, obviously, fixed; the two inner ones were movable. In the *enharmonic* mode the two middle tones were crowded down at the bottom of the tetrachord only a quarter tone (*diêsis*) apart, followed by an interval of two tones ("ditone"). (The term for this "crowding" is *pyknon*). In the *chromatic* the intervals were semitone, semitone, and a tone and a half, or trisemitone. In the *diatonic* (which is the basis of almost all modern Western music), the intervals of the tetrachord were tone-tone-semitone (although not necessarily in that order).

enharmonic: quarter tone, quarter tone, ditone
chromatic: semitone, semitone, trisemitone
diatonic: tone, tone, semitone

Vitruvius gives here a list of the standard names of the intervals and notes covering two octaves and a fourth. He starts with the fixed intervals and then gives the movable intervals, whose various positions determine the type of scale. The terms for the types (or magnitudes) of fixed intervals are these:

i.	diatesseron	fourth
ii.	diapente	fifth
iii.	diapason	octave
iv.	disdiatesseron	octave + fourth
v.	disdiapente	octave + fifth
vi.	disdiapason	double octave

These two octaves and a fourth constituted the range of a lyre (a modern piano covers seven octaves), and the somewhat elaborate Greek names of the specific intervals and notes of this range were based on the names for the strings (*chordai*) of the lyre.[4] The strings used to name the fixed notes were as follows:

Hypatê [chordê] ("uppermost string"): uppermost position, lowest pitch
Mesê [chordê] ("middle string")
Nêtê [chordê] ("lowermost string"): lowermost position, highest pitch
Tritê ("third") occurs between mesê and nêtê; used for movable notes

Tetrachords

lower octave:	
hypaton [systêma]	"lowest system"
meson [systêma]	"middle system"
upper octave:	
synêmmenon [systêma]	"joined system"
diezeugmenon [systêma]	"disjoined system"
upper fourth:	
hyperbolaion [systêma]	"uppermost," "additional system"

The names for the individual notes describe the string (*chordê*), and then end in -ê, or the tone (*tonos*), and then end in -os or the chordal system, and then end in -on.

Fixed Notes

i.	proslambanomenos	added on at the bottom of the scale
ii.	hypatê hypaton	uppermost note on uppermost string
iii.	hypatê meson	middle note on uppermost string
iv.	mesê	middle string
v.	nêtê synêmmenon	joined note on middle string
vi.	paramesê	next to middle string
vii.	nêtê diezeugmenon	low string, disjoined note
viii.	nêtê hyperbolaion	low string, highest note

Movable Notes

i.	parhypatê hypaton	next to uppermost string, uppermost note
ii.	lichanos hypaton	forefinger-struck uppermost note
iii.	parhypatê meson	next to uppermost string, middle note
iv.	lichanos meson	forefinger-struck middle note
v.	tritê synêmmenon	third string, joined note
vi.	paranêtê synêmmenon	next to lowest string, joined note
vii.	tritê diezeugmenon	third string, disjoined note
viii.	paranêtê diezeugmenon	next to lowest string, disjoined note
ix.	tritê hyperbolaion	third string, highest note
x.	paranêtê hyperbolaion	next to lowest string, highest note

In the fifth century B.C. most serious music (i.e., that associated with classical drama) was enharmonic; as Vitruvius says it has "a particularly solemn and dignified authority."[5] Its name means simply "in tune." Chromatic was a sort of deviation, a "coloring" of it (more for "refined pleasure," as Vitruvius says), the province of professional citharodes and with a tendency to "effeminacy." In the Hellenistic period chromatic and diatonic came to dominate because they were easier to appreciate, and by the Late Republic in Rome almost all music was diatonic.

The drawing at the end of Book 5 that Vitruvius refers to was probably very similar to our Figure 81. The custom of illustrating musical intervals by half circles of various diameter is standard for medieval and Renaissance manuscripts.

sharp . . . heavy (5.4.2)

Our "high" and "low" but also related to "sharp" and "flat."

"slow," "looks," flows," "stokes" (5.4.1)

The Latin words are *sol, lux, flos, vox.*

The notes . . . each type (5.4.5)

This is the same use of *genus* as in the "types" of Doric, Ionic, and Corinthian columns.

Echea (Sounding Vessels) (5.5.1–8) (Figure 82)

These vessels, of bronze or clay, may be another example of Vitruvius singling out a highly technical feature of Greek architecture that was uncommon, but between eight and sixteen potential sites with evidence of *echea* have been identified. It is debatable whether such vessels amplified or deadened sound.[6]

that countless theaters
have been built in Rome every year (5.5.7)

For the numerous temporary theaters built for annual festivals in Rome, see Commentary for 10.praef.3.

masonry, stone, or marble, which can not resonate (5.5.7)

In literature poetic fantasy allowed several resonant structures: for example, a musical tower in Megara described by Ovid (*Metamorphoses* 8.14–16).[7]

Lucius Mummius (5.5.8)

Conqueror of Corinth, 146 B.C.

all the artists do their work on it (5.6.2)

Artifices is a fairly common term for actors, especially in the Imperial period.

rotating panels *[periaktoi]* (5.6.3, 5.6.8)

These devices probably go back to the fifth century B.C., but there are almost no archaeological indications of how they functioned in the Hellenistic or Roman theater. From Vitruvius's description they appear to have been rotating prisms that may have been placed behind or in front of the outermost doors of the scene building to indicate locality. To indicate a change of locality within the same town, the convention was to turn only the right *periaktos*; to change the entire scene, both were turned. The right entrance normally indicated an entrance from the town, the left an entrance from the country. To change the scene more than three times, the paintings on the rearward two panels of each *periaktos* could be changed before the next scene change.[8]

lintels (5.6.5)

Supercilia, literally "eyebrows"; these could be archivolts, although in other cases they are flat lintels.

three types of sets (5.6.8)

Reflections of this much discussed passage have been seen in certain types of Pompeiian fresco scenes.[9] Some types of classical tragedy and comedy did continue to be performed, but the most popular types of theater performance were Atellan farce (a sort of commedia dell'arte with stock characters) and mime (a combination of dancers and actors).

The *thymelê* is the altar to Dionysus in the orchestra of a Greek theater (Figure 84). Scenic artists are the protagonist, deuteragonist, and tritagonist; thymelic artists would include the chorus and the aulos player (piper).

2 Aristoxenus, a student of Aristotle, and hence presumably an empiricist, held that precise numerical harmonies could not account for experience on the simple grounds that they were developed from first principles; pleasing harmonies were dependent on slight variations on string length from mathematical prescriptions. This need is recognized in modern "well-tempered" tuning. See T. Levenson, *Measure for Measure: A Musical History of Science* (New York, 1994), 39–70.

3 The following material is derived largely from M. L. West, *Ancient Greek Music* (Oxford, 1992), 160–164, which is the best source for the basics of harmonics.

4 Our thanks for the following to the composer Lou Harrison.

5 M. L. West, *Ancient Greek Music* (Oxford, 1992), 164.

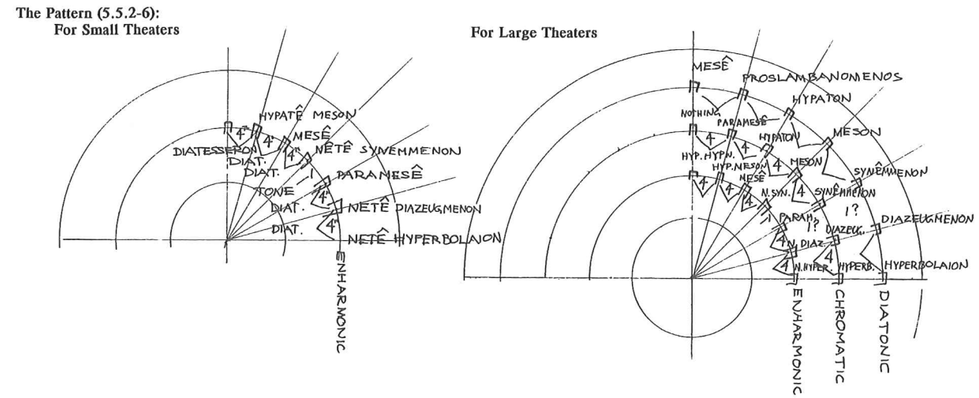
6 On pithoi beneath the floor causing the house auditorium to resound, Aristotle *Problemata* 9.8; on empty pots deadening sound, Pliny the Elder, *Natural History* 11.12.270. On eight potential sites with evidence of *echea*, P. Thielscher, "Die Schallgefässe des antiken Theaters," *Festschrift Frans Dornseiff*, ed. H. Kusch (Leipzig, VEB Bibliographisches Institut, 1953), 334–371. Our thanks to Profs. Jean Davison and Robert Arns of the University of Vermont for information on their researches; article forthcoming in *Technology and Culture.*

7 Also Horace, *Carmina* 3.11.2, "movit Amphion lapides canendo," and Statius, *Thebaid* 1.9 seq.

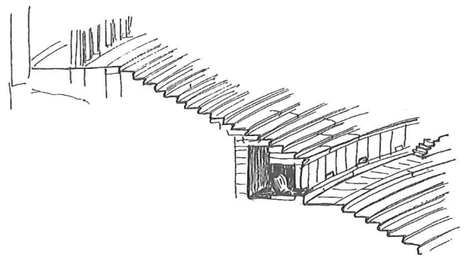
8 See M. Bieber, *The History of the Greek and Roman Theater* (Princeton, 1961), 75.

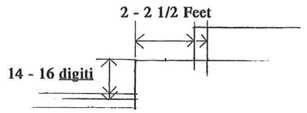
9 H. G. Beyen, "The Wall Decoration of the Cubiculum of the Villa of Publius Fannius Synistor near Boscoreale in Relation to Ancient Stage Painting," *Mnemosyne* 4th ser. 10 (1957), 147–153; A. M. G. Little, *Roman Perspective Painting and the Ancient Stage* (Kennebunk, Maine, 1971); R. Ling, *Roman Painting* (Cambridge, 1990), 30–31, 77–78, 143.

ECHEA (SOUNDING VESSELS IN THEATERS) (5.5.1-8)



Theater of Aizanoi (Turkey)
[after J. Durm, Baukunst der Griechen (Leipzig, 1910), 467, fig. 420.]





Vitruvius 5.3.4, 5.5.1

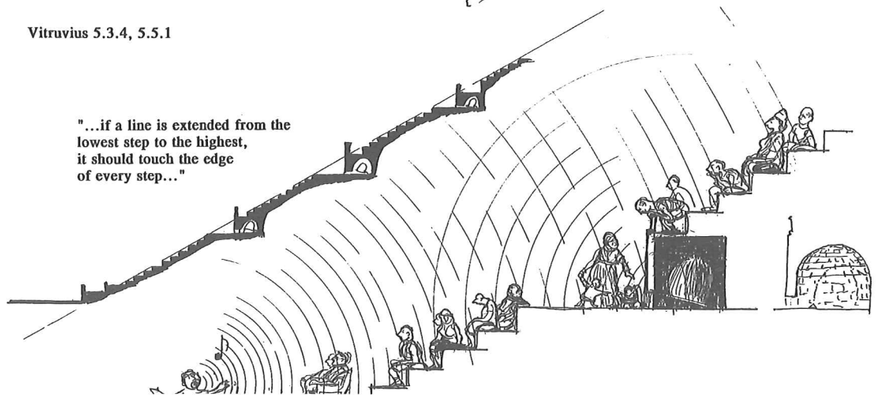


Figure 82. *Echea* (Sounding Vessels in Theaters) (5.5.1–8).

THEATER DESIGN: THE ROMAN THEATER (5.6.1-8)

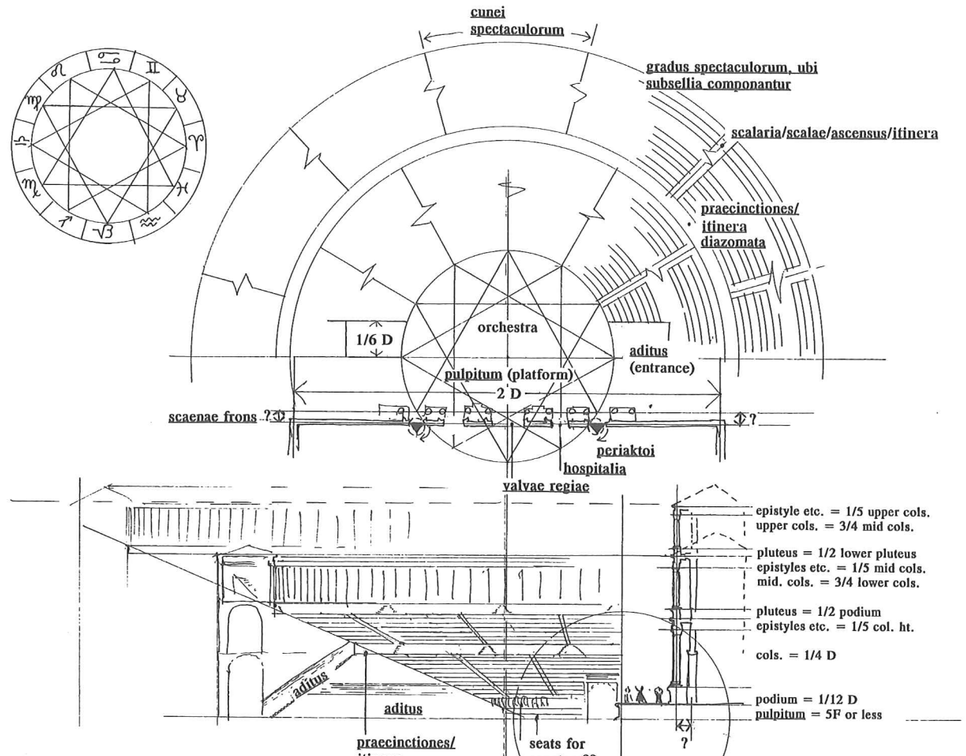
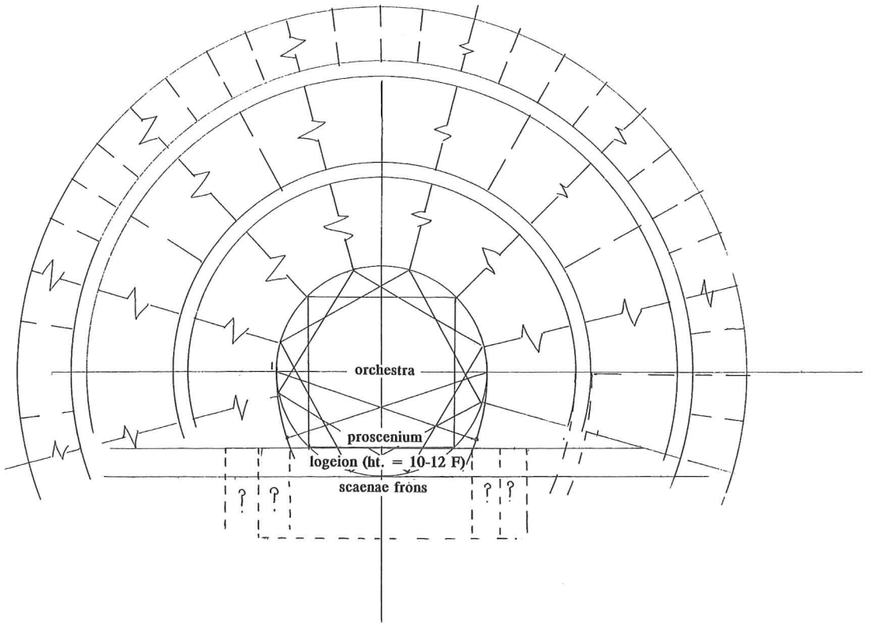


Figure 83. Theater Design: The Roman Theater (5.6.1–8).

THEATER DESIGN: THE GREEK THEATER (5.7.1-2)



GREEK THEATERS
[after Bieber, The History of the Greek and Roman Theater (Princeton, 1961), fig. 476.]

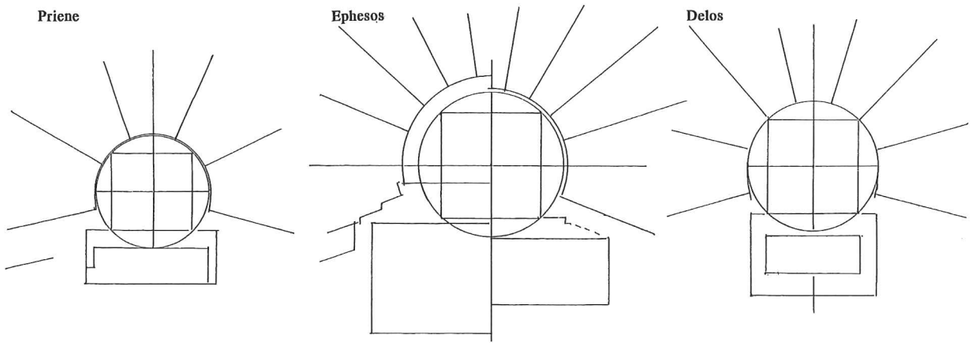


Figure 84. Theater Design: The Greek Theater (5.7.1–2).

Behind the scene building,
set up porticoes (5.9.1) (Figure 85)

Vitruvius refers in part to the great quadriporticus attached to buildings like the Theater of Pompey, but the custom of building porticoes of some sort in the region of theaters goes back to the late classical period (see figure). As Vitruvius implies, these could be remarkably multifunctional spaces. The Senate sometimes met in the porticus behind the Theater of Pompey (as it did on the Ides of March, 44), and the Saepta, the huge courtyard built by Caesar as a voting precinct, also housed gladiatorial games.

supplying the wood . . . in great quantities (5.9.8)

Roman cities did indeed consume a great quantity of wood, especially for baths and industry, and the huge consumption has been linked to deforestation and the silting of harbors in late antiquity.

the explanation of bath design . . . (5.10.1–5) (Figures 86, 87)

In the view of the old-fashioned moralists, baths were part of the disintegration of morals not only because they attracted purveyors of corruption and ease, but also because heat was considered enervating (cf. 1.4.6).[10]

stucco or plaster (5.10.3)

Albario (here translated "stucco") implies worked, molded plaster; *tectorio* implies plaster, including the fresco layer.

Spartan sauna and sweating chambers (5.10.5)

Laconicum, a dry heat chamber with, or near, a cold water plunge, that is, bathing in the Spartan manner; *sudatio*, wet heat, or steam room.

building palaestras (5.11.1) (Figure 88)

In Greek usage a palaestra was a wrestling school and a building, usually a courtyard building. A gymnasium was an athletic ground, with or without buildings, mainly equipped with running tracks, and almost always public. The palaestra could often be privately owned, but also often city owned, and was the main place of instruction for ephebes.[11]

BOOK 6

Aristippus (6.praef. 1)

Aristippus of Cyrene, a contemporary and associate of Socrates, and a man of luxurious habits, or his grandson, a founder of the Cyrenaic school of philosophy, which taught a sensationalist theory of knowledge and that immediate pleasure is the goal of action.

10 Seneca, *Epistulae* 51.6, *Dialogi* 7.7.3. See C. Edwards, *The Politics of Immorality in Ancient Rome* (Cambridge, 1993), 175–193.
11 E. N. Gardiner, *Athletics of the Ancient World* (Oxford, 1930; reprint Chicago, 1980).

Theophrastus . . . a citizen in every country (6.praef.2)

Presumably Theophrastus, successor of Aristotle at the Lyceum.

The poets who wrote those old comedies . . . (6.praef.3)

Eucrates and Chionides and, of course, Aristophanes were the poets of Old Comedy (mid/late fifth century B.C.); Alexis was a poet of Middle Comedy (c. 375 B.C.).

And therefore I thank my parents immeasurably . . .
an art . . . that can not be mastered without
education in letters and comprehensive learning (6.praef.4)

The type of education that Vitruvius refers to (*litteratura encyclioque doctrinarum omnium disciplina*) would have been contracted out by his parents to several different specialist teachers while he was in his middle teens, which would have been a considerable expense to a family of modest means.

both literary and technical writing (6.praef.4)

The distinction between *philologia* and *philotechnia* is observed in Greek technical literature (e.g., Philo of Byzantium). These technical writers make very little use of literary devices in the manner of Vitruvius's treatise.

make the rounds (6.praef.5)

Presumably Vitruvius means that architects appeared among the crowds of clients who visited the atria of prominent Romans during the morning ritual known as the "greeting," *salutatio*. The reading chosen here, *ambiunt*, is directly related to the English word *ambition*. The oldest manuscript of Vitruvius contains another word, *ambigunt*, whose meaning is "they wander about."

good family (6.praef.6)

Ingenuo pudori implies strongly that Vitruvius and his parents are freeborn citizens.

private buildings (6.praef.7)

Vitruvius studiously avoids using the word *domus*, "house," except when referring to the public spaces of the most sumptuous houses.

latitudes (6.1.1) (Figure 90)

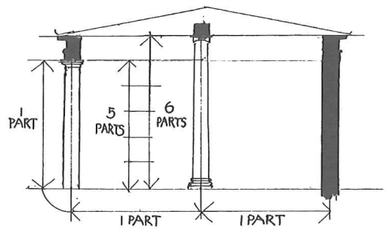
Climata. The idea that national or racial characteristics are created or shaped by climate goes back to the Ionian philosophers.[1]

signbearing circle (6.1.1)

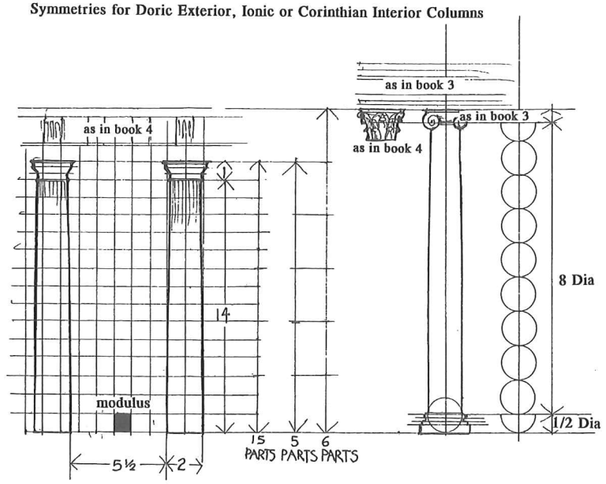
Vitruvius always refers to the zodiac by this or other circuitous Latin phrases because "zodiac" is a specifically Greek term rather than a native one.

1 See also Herodotus 9.122; Euripides *Medea* 826 seq.; Seneca *Epistulae* 51.10, Lucian 8.363–368. On the Augustan ideal of Italy as the land of the Golden Mean (as far as climate and temperament go), Virgil, *Georgics* 2.136–176. Caesar, on the other hand, praises the ingenuity of northern-dwelling, thick-air breathing Gauls (*De Bello Gallico* 7.22).

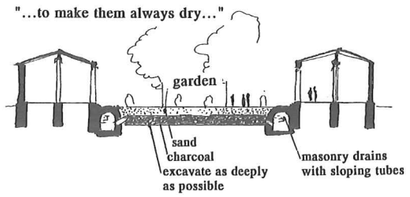
PORTICOES (5.9.1-9)



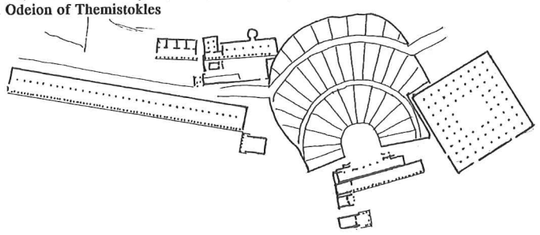
Symmetries for Doric Exterior, Ionic or Corinthian Interior Columns



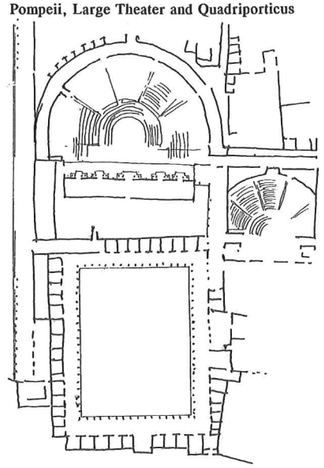
"...to make them always dry..."



Athens, Theater of Dionysos, Stoa of Eumenes, and Odeion of Themistokles



Pompeii, Large Theater and Quadriporticus



Rome, Theater and Porticus of Pompey
(partly reconstructed after the Forma Urbis)

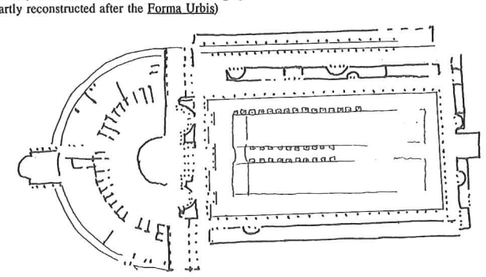
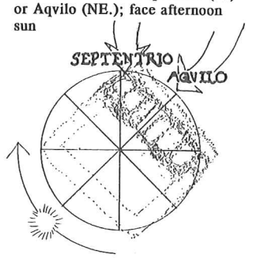


Figure 85. Porticoes (5.9.1–9).

BATHS BALNEAE (5.10.1-5)

Orientation: avoid Septentrio (N.) or Aqvilo (NE.); face afternoon sun



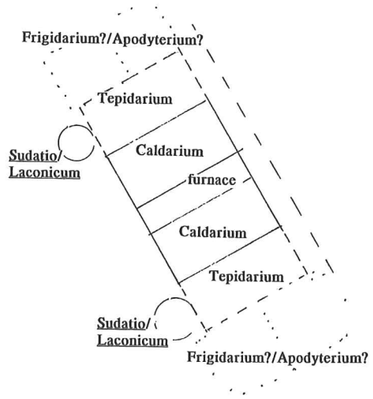
General Layout:
-facing SW or W (afternoon sun)

-men's and women's caldaria in same area to share common furnace

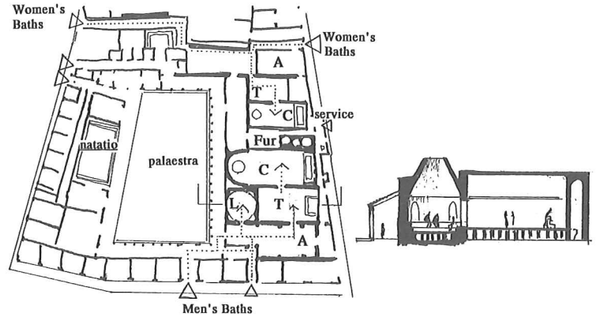
-sudatio/laconicum attached to tepidarium

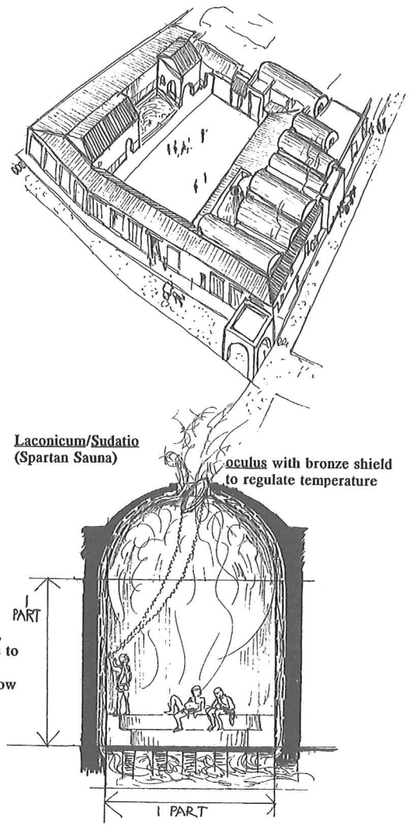
-frigidarium (location unspecified)

(-apodyterium, dressing room, not mentioned)



Pompeii, Stabian baths, as in c. 80 B.C.: plan, section through laconicum and tepidarium, and reconstruction. [Reconstruction after H. Eschebach, Die Stabianerthermen in Pompeii (Berlin, 1979).]





Balneae (Bathing Rooms)

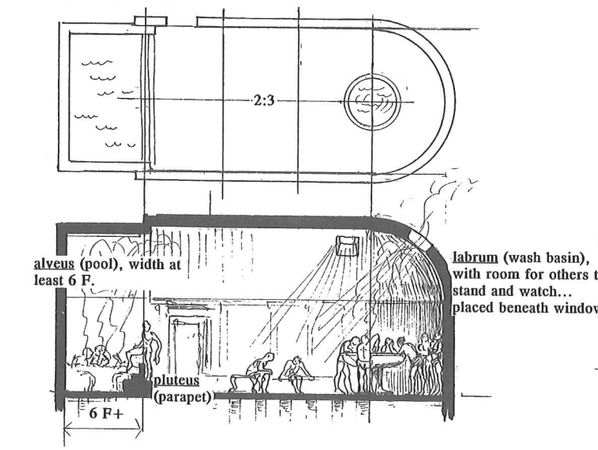
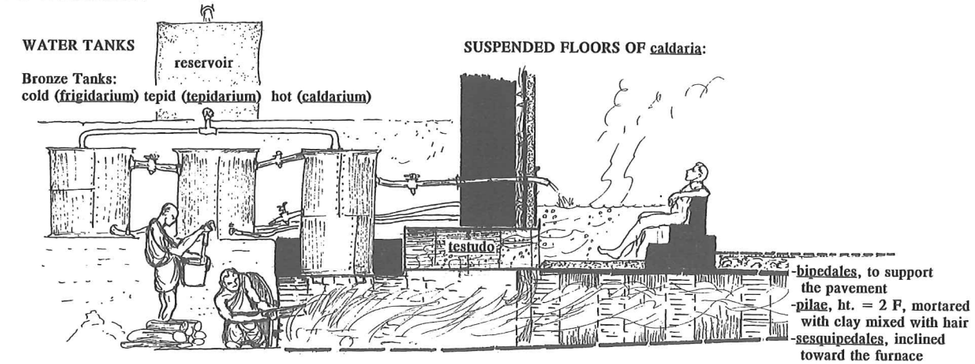


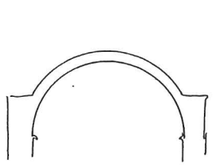
Figure 86. Baths (*Balneae*) (5.10.1–5).

BATHS BALNEAE (5.10.1-5)

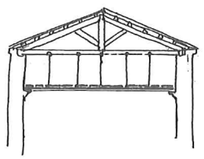


CEILINGS/VAULTS

concamerationes (chambering, ceiling)
"are more efficient if made of masonry."

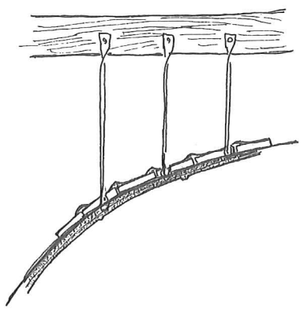


Flat Ceilings (Suspended)



Arched Ceilings (Suspended)

Double Ceilings (for caldaria)



Ceilings made of timbers:

-iron hooks

-rods (for flat ceilings) or arcs (for vaulted ceilings), set in rows to support flat tiles.
-upper surface: joints spread with clay and hair.
-flat tiles.
-under surface: plastered with lime and terracotta; then albarium or tectorium

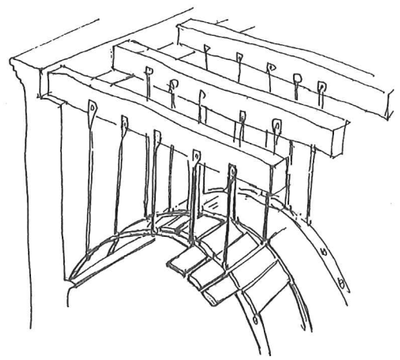
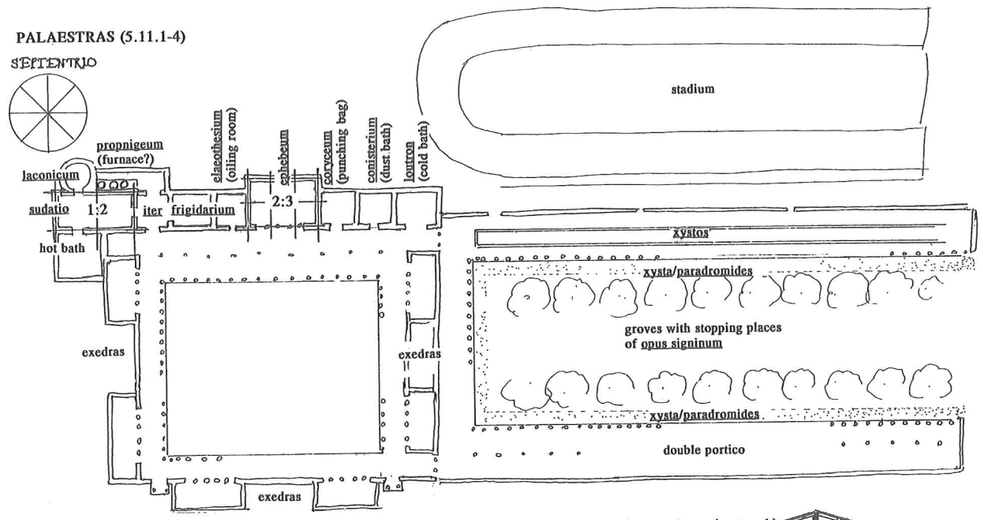
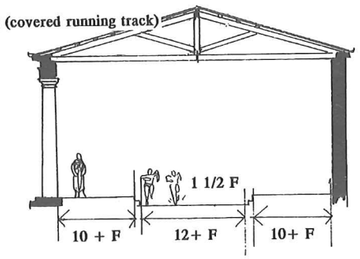


Figure 87. Baths (*Balneae*) (5.10.1–5).

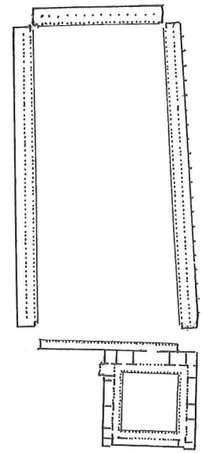
PALAESTRAS (5.11.1-4)



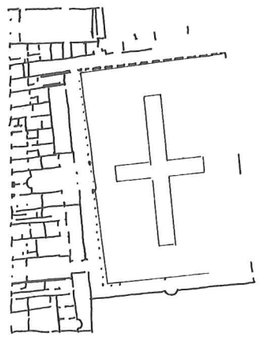
xystos (covered running track)



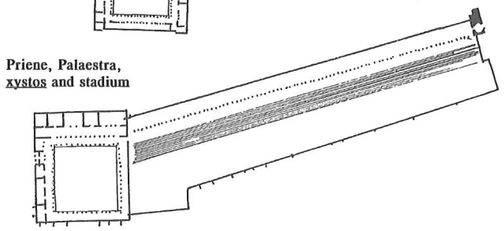
Olympia, Gymnasium and Palaestra



Herculaneum, Palaestra



Priene, Palaestra, xystos and stadium



Pompeii, Palaestra and Amphitheater

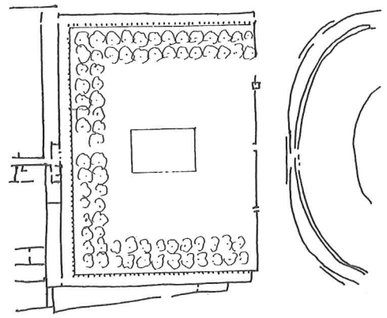
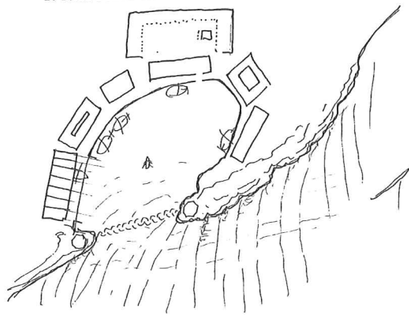


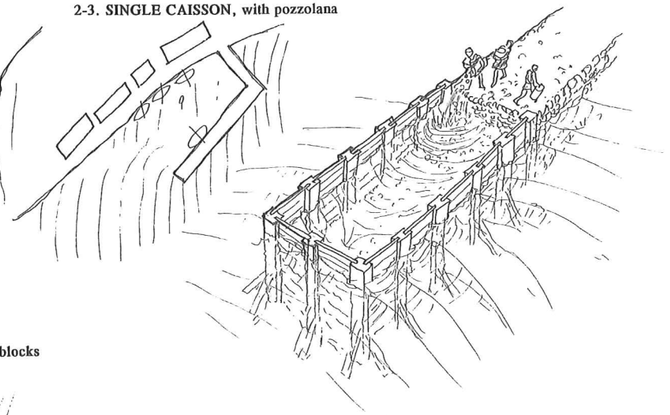
Figure 88. Palaestras (5.11.1–4).

PORTS/MOLES (5.12.1-7)

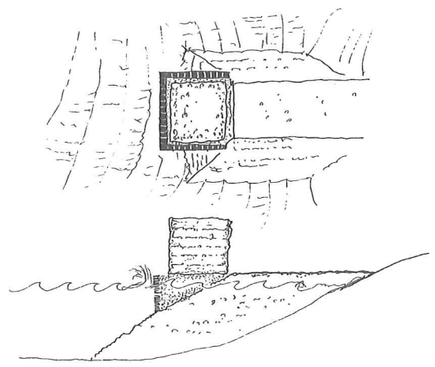
1. NATURAL HARBOR



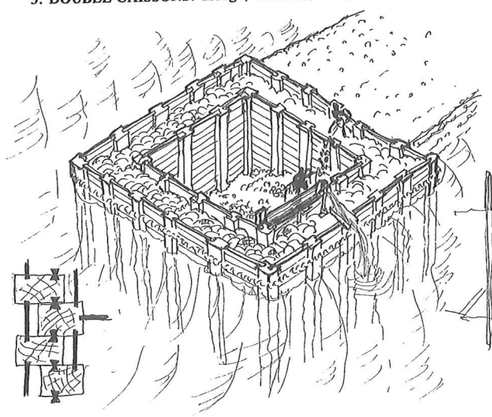
2-3. SINGLE CAISSON, with pozzolana



4. IN ROUGH WATER: build cushion, tumble blocks



5. DOUBLE CAISSONS: dredge, excavate, dump rubble



6. IF SOFT GROUND: pilings, ashlar, concrete

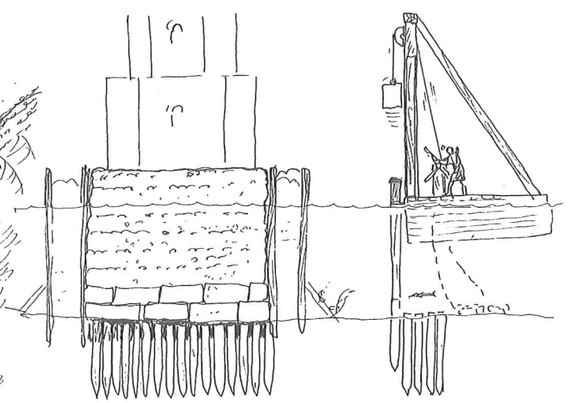
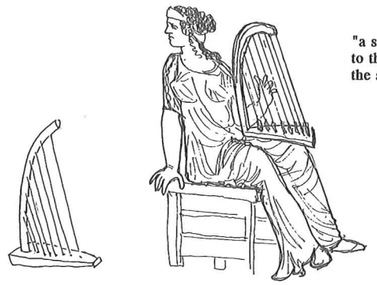


Figure 89. Ports/Moles (5.12.1–7).

LATITUDES, PEOPLES AND MUSICAL INTERVALS (6.1.1-12)



"a line...from the margin in the northern region to the margin above the southern axis..."

"the nations that have been nutured in the north...."

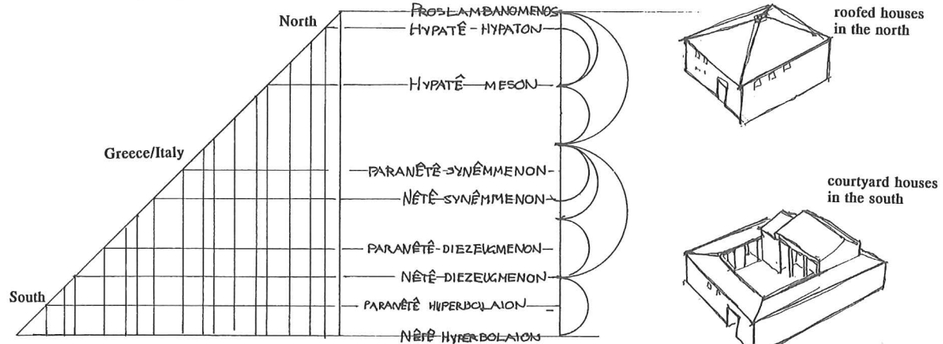
"a second oblique line...cast upward to the top of the hinge beyond the stars to the north..."

"those who are nearest the southern axis..."

area of the hottest sun (the belt of signs)

"endpoints of the east and west...by which the upper and lower parts of the cosmos are divided..."

sambuca (sambykê)
[right, based on a fourth cent. B.C. Apulian pelike, Copenhagen viii 316, ill. in M.L. West, Ancient Greek Music (Oxford, 1992), pl. 7.]



roofed houses in the north

courtyard houses in the south

The Harmony of the Spheres, i.e., the distances of the planetary orbits represented as musical intervals covering an octave (here, two disjunct tetrachords), based on Pythagorean philosophy and physics. Highest tones are outer orbits.
[based on a medieval ms., ill. in O. Pederson, M. Pihl, Early Physics and Astronomy (New York and London, 1974), fig. 6.1.]

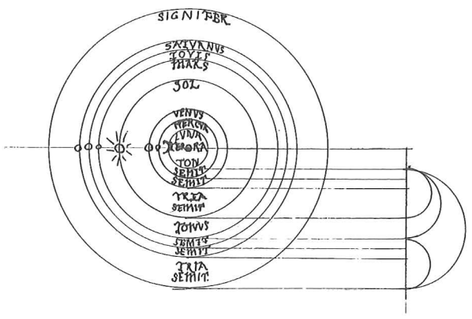


Figure 90. Latitudes, Peoples, and Musical Intervals (6.1.1–12).

the sun placed naturally
at an incline . . . with dissimilar qualities (6.1.1)

This is another reference to the idea that the dissimilarity of terrestrial phenomena is caused by the rotation of cosmic spheres and particularly the obliquity of the ecliptic.

that the firmament has the shape of a triangle . . . like . . .
the *sambykê* (6.1.5) (Figure 90)

The key to understanding this rather difficult image, which is probably Vitruvius's own invention, is that, although technically all places on the earth's surface are equidistant from the firmament (the sphere of stars), he is thinking of distance north being "up" from that part of the earth which is hottest and "closest to the firmament," that is, the equatorial regions.

conjunction of the cosmos (6.1.8)

Language borrowed from astrology.

partake in equal measure (6.1.11)

Temperatissimae, tempered, is language borrowed from chemistry. Tempering means the proper balance of elements appropriate to the object or being, which guarantees its integrity or vigor.

alae . . . tablinum . . . (6.3.4.5) (Figure 92)

The functions of the rooms in a house are hard to define, probably in part because they were highly multifunctional. The *tablinum* apparently began as the principal dining room of the *domus,* but its primary function came to be the usual place where the *dominus* of the house, seated, with secretaries and others, conducted the business of the morning *salutatio* with clients. The *alae* might have served as any other kind of "breakout" space, for example, for dining for an entourage or multiple groups at a banquet (a pattern maintained in Imperial dining areas). The tablinum became little more than a passage to a garden peristyle but may still have functioned as the normal seat of the *salutatio.*

peristyle courtyards . . . triclinia . . . picture
galleries . . . oecus . . . libraries . . . baths . . .
winter/summer dining rooms (6.3.7–11, 6.4.1–2) (Figure 93)

This list of elegant specialized rooms is a trait of the spectacular luxury villas and domus of the late Republic. The triclinium (a three-couch dining room) and oecus became the principal types of dining room. It is unclear what was meant by an oecus; it is probably simply a fashionable "Grecian" equivalent of an ornamental triclinium.

cubicula (6.4.1)

The cubiculum was the private bedchamber of those members of the family whose status merited it. But it also served as the place for those family members to do business with other family members or intimate friends that could not be dealt with in the more public space of the atrium.

the most prominent citizens . . . for in the
homes of these people . . . both public
deliberations and private judgments . . . (6.5.2)

The business carried on with guests and clients in the cavaedia of prominent citizens was very much an extension of the public affairs. It may have been a new custom of the period to hold trials in the private *domus* of the magistrates. Trials were normally held out of doors in the Forum or in basilica.[2]

rural buildings (6.5.3; 6.6.1–6) (Figure 95)

Vitruvius does not talk about the distinction between pars (sub-)urbana, pars rustica, the elegant residential versus agricultural/industrial parts of the villa. The implied combination comes only at the end of this section; the term *villa urbana* comes from Varro.[3]

The Greeks do not use atria . . . (6.7.1–5) (Figure 97)

The source of Vitruvius's ideas for the planning of a "Greek" house is highly debatable, but then there is probably no real "source." The image, or program, given here is likely an amalgam or analytic invention of Vitruvius based on typical Greek multicourt peristyle palaces (e.g., Pella, Pergamum, presumably Alexandria; other large Greek houses and palaces – for example, Vergina – were often just a single courtyard), common hearsay about the social segregation of Greek women, compounded with images of Pompeiian atrium-peristyle houses, which are palatial in scale. (The House of the Faun at Pompeii is larger than any known Hellenistic ruler's palace.) J. Raeder[4] has suggested that *gynaikonitis* probably meant the general living quarters, the *andronitis* the representational quarters, those dominated by men, sometimes excluding women. These terms probably were used to distinguish between types of apartments on Delos when there was a major presence of Italian businessmen there. In any case, Vitruvius's discussion of houses, Greek and Roman, deals with the very highest level of status.

larger residential quarters (6.7.3)

Here the word *domus* is used for the first time since Book 2.

convenient dining rooms (6.7.4)

A euphemism for small *(commoda).*

When the Greeks were more
refined and more wealthy (6.7.4)

This suggests that Vitruvius's description is taken from some past time, presumably before the decline of Greek independence, c. 198–145 B.C.

2 The trial for which Cicero delivered *For King Deioarches* was held in Caesar's house. G. Kennedy, *A New History of Ancient Rhetoric* (Princeton, 1994), 150.
3 *De Re Rustica* 1.13.6.
4 *Gymnasium* 95 (1988), 316–368.

TYPES (GENERA) OF INTERIORS (CAVAEDIA) (6.3.1-2)

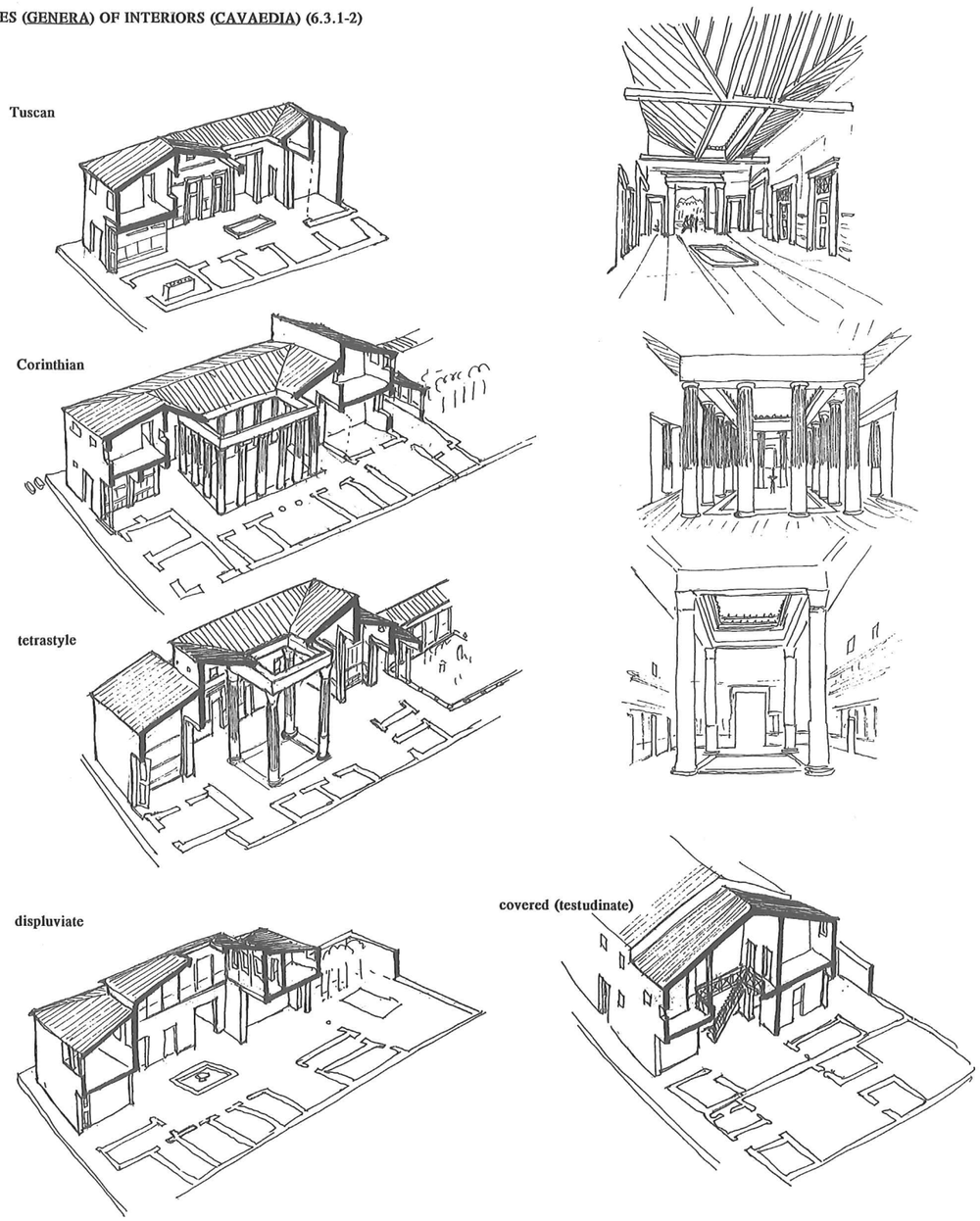
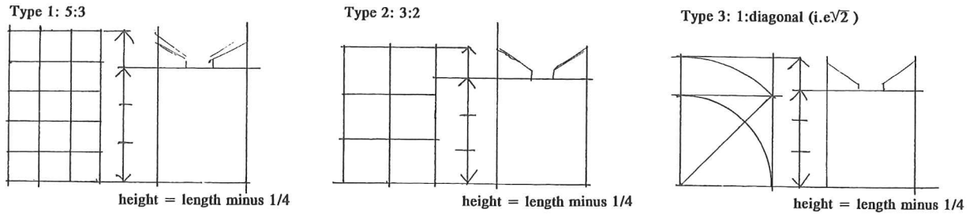


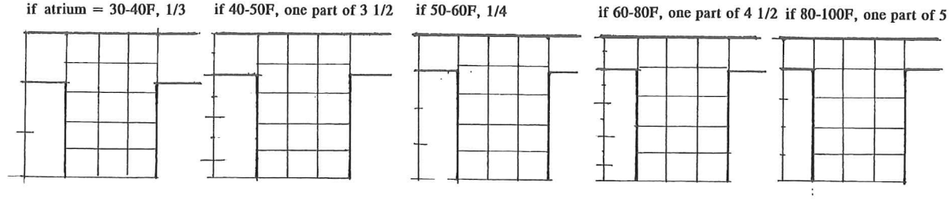
Figure 91. Types (*Genera*) of Interiors (*Cavaedia*) (6.3.1–2).

PROPORTIONS OF ATRIA (6.3.3-6)

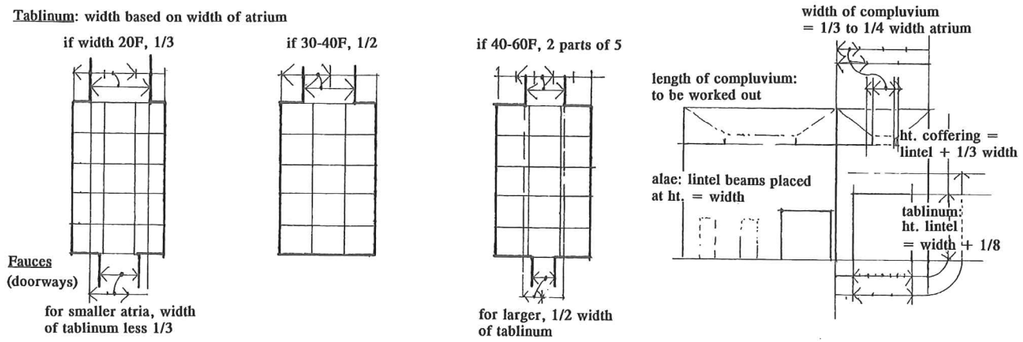
Types of atria:



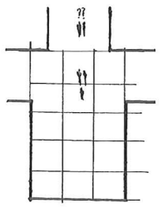
Alae: width based on length of atrium
(drawn with Type 1 atrium)



Tablinum: width based on width of atrium



"If we use the proportions of smaller atria to design the larger ones, the dependent rooms will seem vacant and oversized."



"If we use the proportions of larger atria in the design of smaller ones, the tablinum and alae will seem too small..."

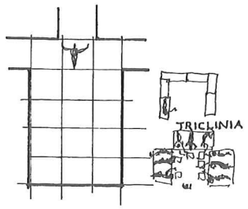
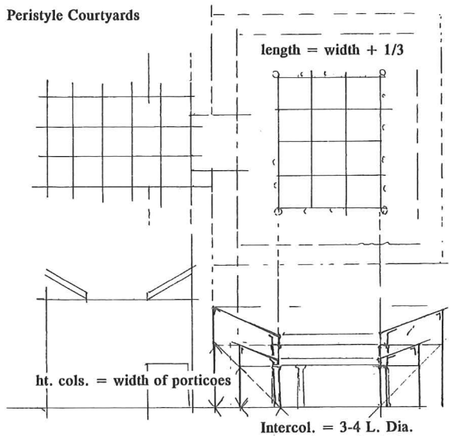


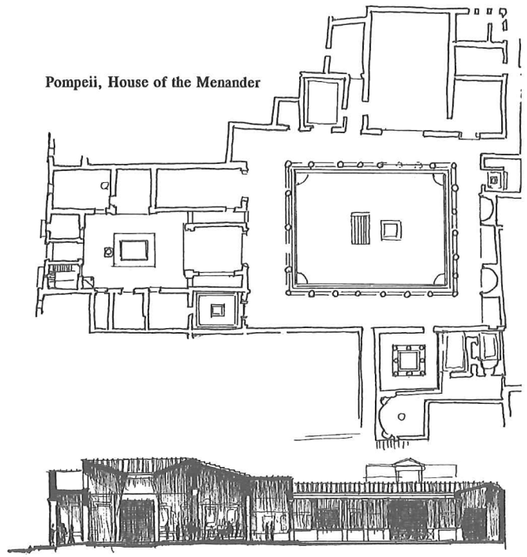
Figure 92. Proportions of *Atria* (6.3.3–6).

PERISTYLE COURTYARDS AND DEPENDENT CHAMBERS (6.3.7-11)

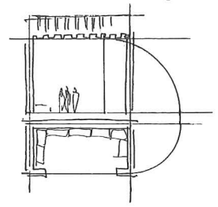
Peristyle Courtyards



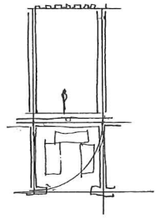
Pompeii, House of the Menander



Triclinia:
-length = twice width
-hts. all enclosed rooms =
half the sum of width and length

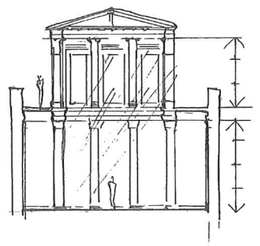


Exedrae/Oeci:
-hts. of exedrae or square oeci =
one and a half times width

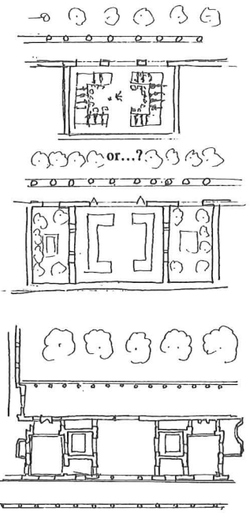


Pinacothecae (Picture Galleries):
-like exedrae

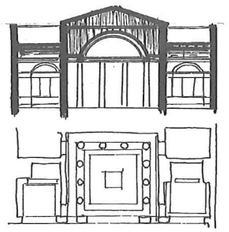
Egyptian Oecus
(above: Vitr. 6.3.9)
(below: Herculaneum, House of
the Mosaic Atrium, after Maiuri)



Cyzicene Oecus
-north aspect, garden view
-folding doors & windows
-right and left windows with
view of garden
-broad/long enough for two triclinia
-height = 1/2 width
(below, oeci-summer dining rooms
in the villa at Oplontis)



Corinthian Oecus
(Pompeii, House of the Labyrinth)



Tetrastyle Oecus
(Pompeii, House of the Silver Wedding)

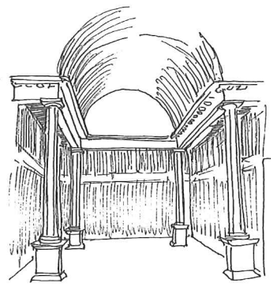
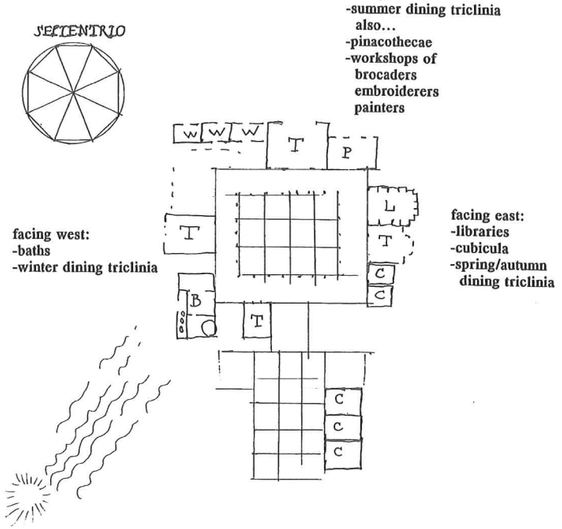
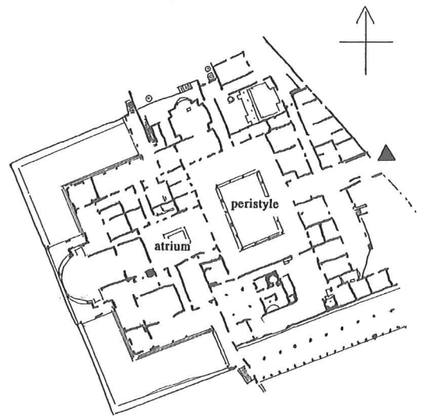


Figure 93. Peristyle Courtyards and Dependent Chambers (6.3.7–11).

ORIENTATION OF ROOMS (6.4.1-2)



"...in the city atria customarily come next to the entrance, whereas in the country and the pseudo-urban buildings, the peristyle comes first..." (6.5.3)
(Pompeii, Villa of the Mysteries)



DIVISION OF PUBLIC vs. PRIVATE AREAS (6.5.1)

Private:
-cubicula
-triclinia
-baths
-etc. (service?)

Public...accessible even to the uninvited (??)
-vestibules
-cavaedia
-peristyles...
-etc. ("basilicas?")

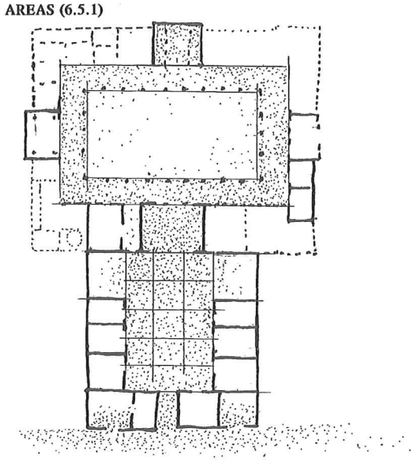
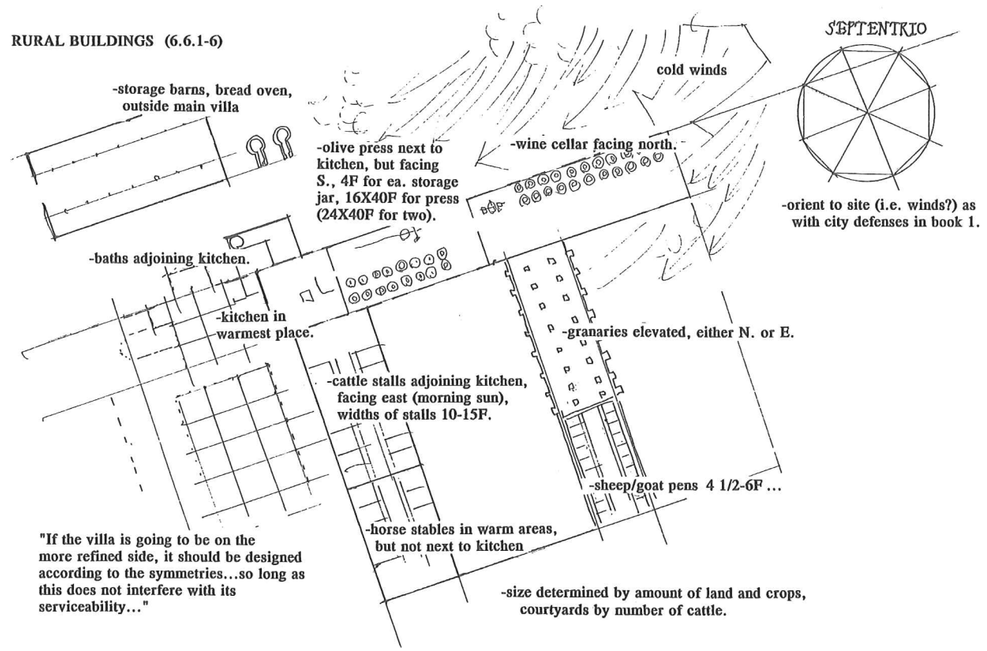
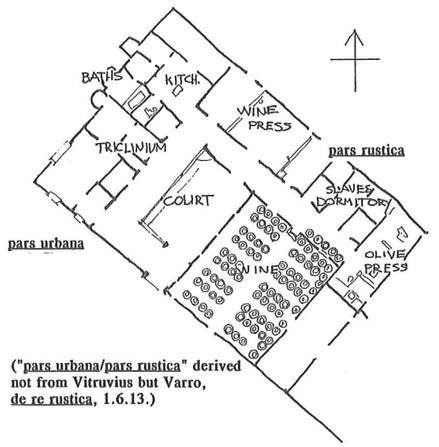


Figure 94. Orientation of Rooms (6.4.1–2).

RURAL BUILDINGS (6.6.1-6)



Boscoreale, Villa Rustica "alla Pisanella"



("pars urbana/pars rustica" derived not from Vitruvius but Varro, de re rustica, 1.6.13.)

The villa of Settefinestre
(reconstruction after Carandini)

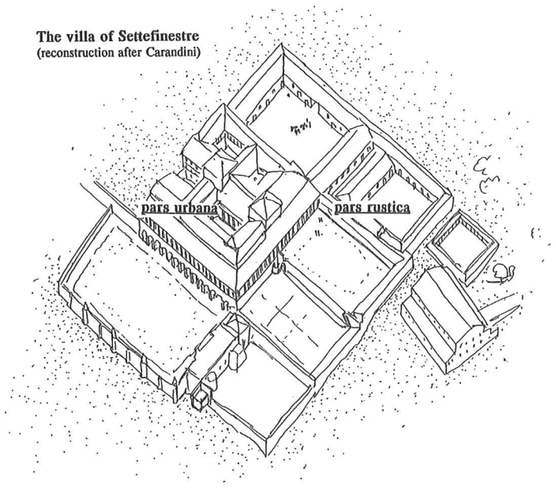
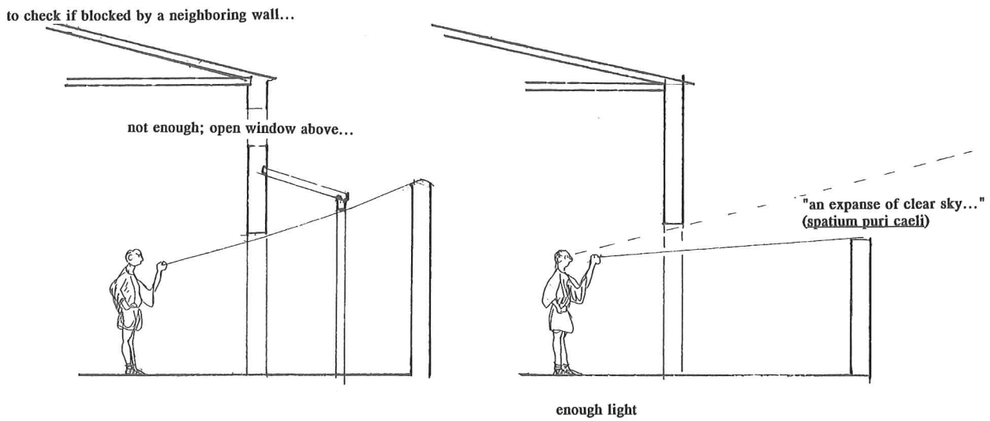


Figure 95. Rural Buildings (*Rusticorum Aedificiorum Expeditiones*) (6.6.1–6).



Seasonal sunlight in the courtyard of a typical house in Priene
[after W. Hoepfner, W.D. Heilmeyer, Haus und Stadt im klassischen Griechenland (Munich, 1994²), fig. 303.)

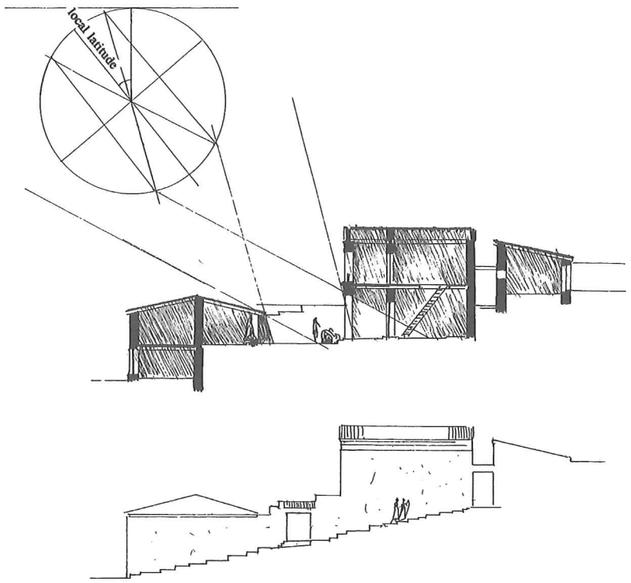


Figure 96. Natural Lighting (6.6.6–7).

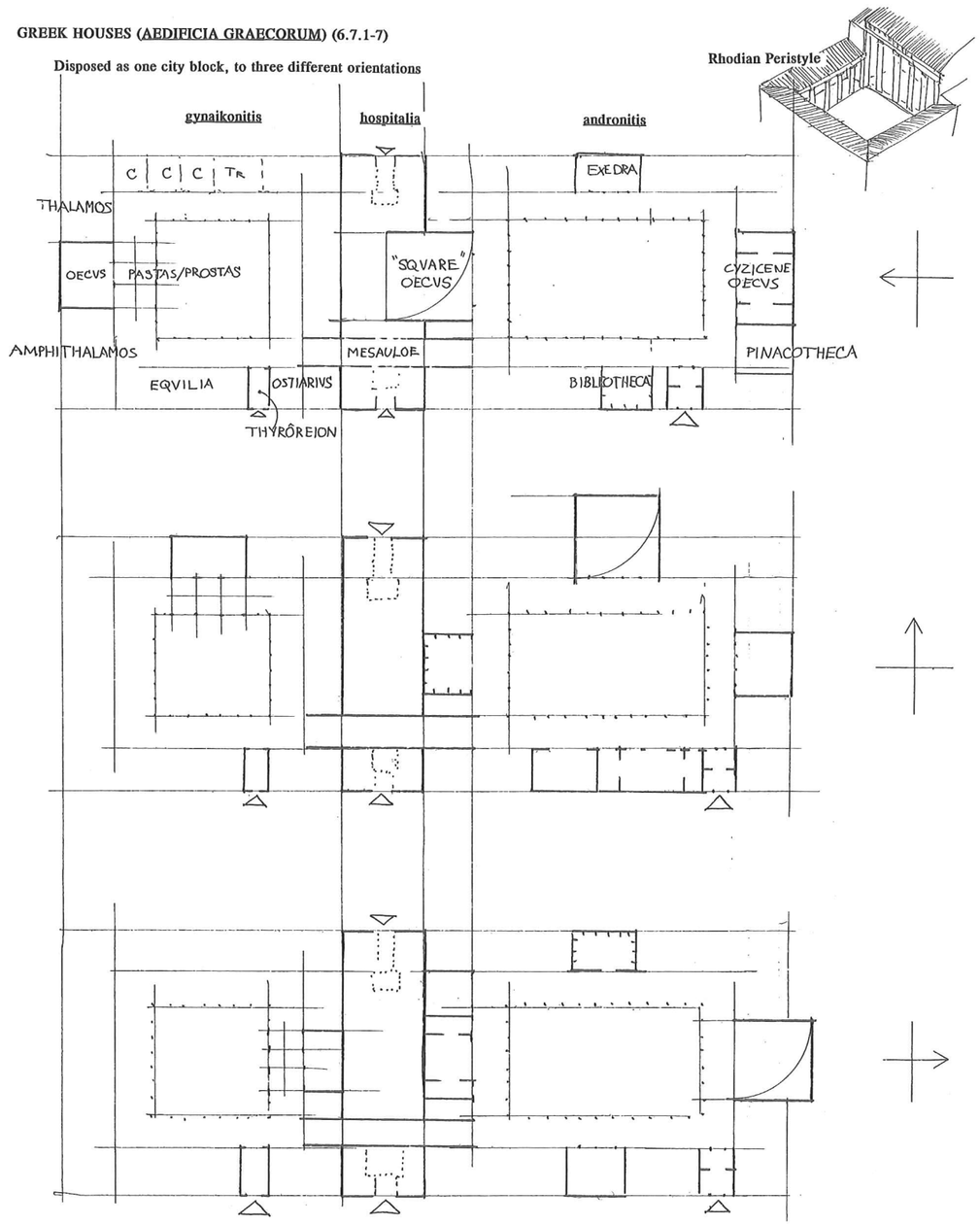
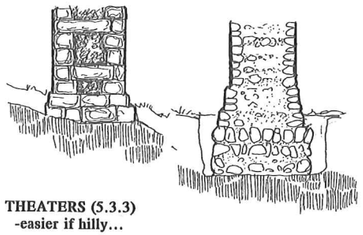


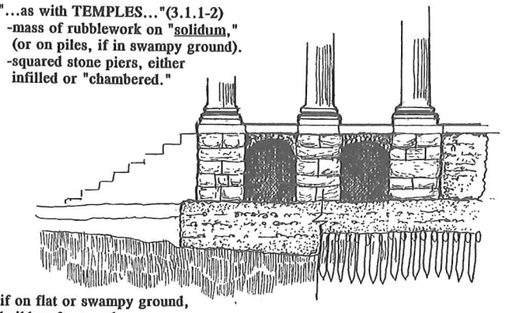
Figure 97. Greek Houses (*Aedificia Graecorum*) (6.7.1–7).

MORE ON FOUNDATIONS (summary...)(6.8.1)

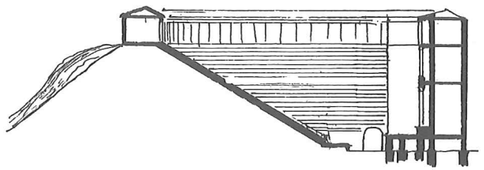
"...as for CITY DEFENSES..."(1.5.1)
-excavate "ad solidum."
-foundations wider than walls.



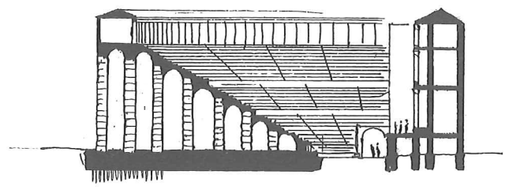
"...as with TEMPLES..."(3.1.1-2)
-mass of rubblework on "solidum,"
(or on piles, if in swampy ground).
-squared stone piers, either
infilled or "chambered."



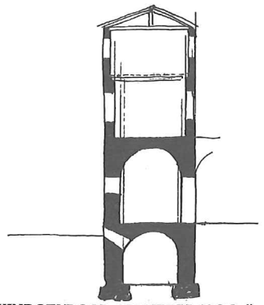
THEATERS (5.3.3)
-easier if hilly...



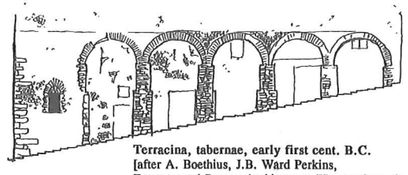
-if on flat or swampy ground,
build as for temples...



UNDERGROUND ROOMS (hypogea) (6.8.1)
-foundations thicker than upper parts.
-upper walls centered over lower.

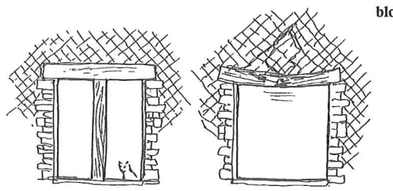


-for buildings built on PIERS AND VAULTS (6.8.4)
the outermost piers should be made wider than the rest



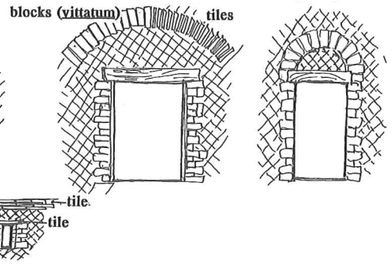
Terracina, tabernae, early first cent. B.C.
[after A. Boethius, J.B. Ward Perkins,
Etruscan and Roman Architecture (Harmondsworth,
1970) fig. 67.]

WINDOW/DOOR OPENINGS (6.8.2-4)
-posts between piers or antae...



Ostia, window in
republican horrea

-relieving arches, centered over openings...



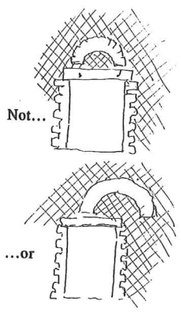
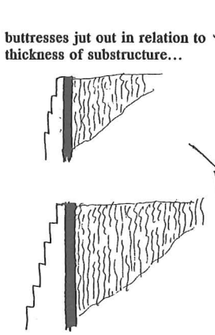
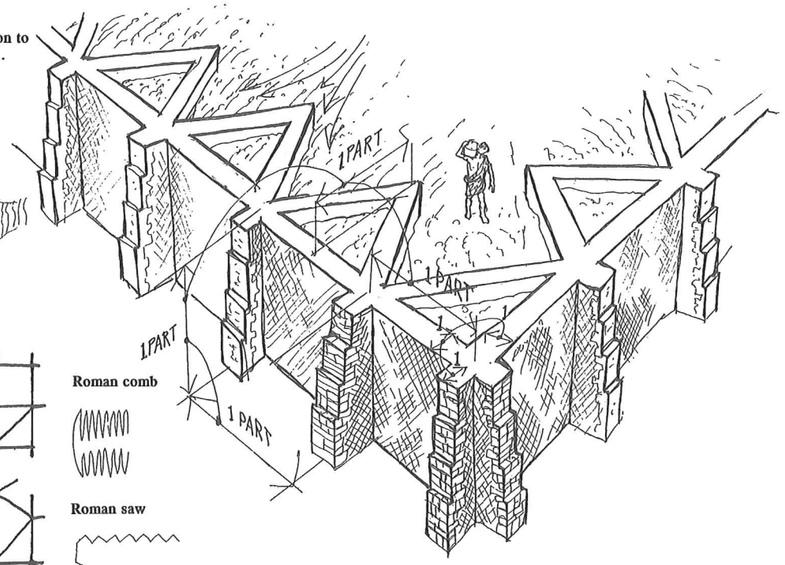


Figure 98. More on Foundations (Summary: 6.8.1; 1.5.1; 3.1.1–2; 5.3.3; 6.8.1; 6.8.2–4; 6.8.4).

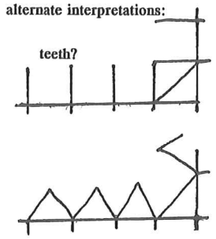
RETAINING WALLS AND BUTTRESSES (anterides/erismae) (6.8.6–7)

buttresses jut out in relation to
thickness of substructure...





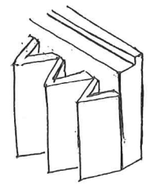
alternate interpretations:



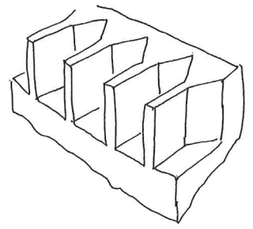
Roman comb

Roman saw

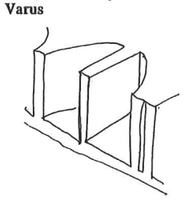
Palatine, Domus Flavia



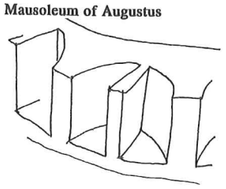
Tivoli, Villa "of Horace"



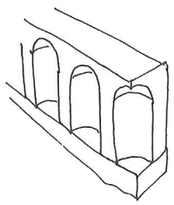
Tivoli, Villa of Quintilius Varus



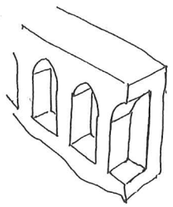
Mausoleum of Augustus



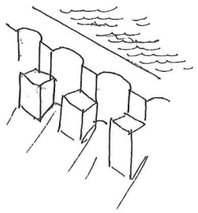
Todi



Tivoli, Villa "of Cassius"



Merida (Spain), dam



Basilea, theater

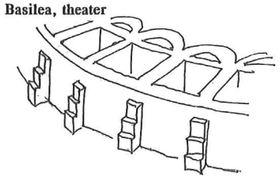


Figure 99. Retaining Walls and Buttresses (*Anterides sive Erismae*) (6.8.6–7).

an appropriate term either in Greek or in Latin (6.7.5)

This passage addresses the technical problems of many Latin writers of the first century B.C.: how to develop Latin equivalents for essential Greek terms.

underground rooms or chambers (6.8.1) (Figure 98)

hypogea concamerationesque. Concameratio, at least in this instance, presumably means vault, but the literal meaning is "chamber." Discussions of foundations are scattered in several places in the *Ten Books:* 1.1.5, fortifications sunk to solid; 3.4.1–2, on temple foundations, presumably the main section; 5.3.3 on theaters, built as recommended for temples; 5.12.1–7, harbor moles; 8.16.14, *opus signinum* in trenches.

voussoirs (6.8.3)

Vitruvius's use of the word *cuneus,* wedge, makes it clear that he means a real keystone arch with wedge-shaped voussoirs, both here and in 6.8.4.

and the quality of the design (6.8.9)

Dispositione (disposition).

BOOK 7

Thales, Democritus, Anaxagoras, Xenophanes (7.praef.2)

This is a partial, and not strictly chronological, list of "classic" natural philosophers: Thales of Miletus (fl. c. 580 B.C.), the first of the Ionian philosophers; Democritus of Abdera (c. 460–c. 365 B.C.), founder of atomism; Anaxagoras of Clazomenae (c. 500–428 B.C.), master of Euripides, an astronomer, formulator of theories of perspective; Xenophanes of Colophon (fl. c. 540 B.C.).

Socrates, Plato, Aristotle, Zeno, Epicurus (7.praef.2)

These two lists follow the distinction between physical and moral philosophy, the first being moral, the second being physical, although most members of this second group would also classify as natural philosophers.

Croesus, Alexander (7.praef.2)

Croesus of Lydia (560–546 B.C.), Alexander the Great (336–323 B.C.).

the great library of Pergamum (7.praef.4); Aristophanes (7.praef.5)

The library at Alexandria was traditionally founded in 307 by Ptolemy I Sotêr, supposedly with the help of Demetrius of Phalerum. The library at Pergamum was founded afterward by Eumenes II (197–159). Pliny the Elder reports that the political rivalry between the Ptolemies of Egypt and the Attalids of Pergamum had an impact on the libraries because Ptolemy V Epiphanes (205–182), jealous of Pergamum's success, placed an embargo on the export of papyrus, leading the Pergamenes to invent parchment for writing (the word for parchment in German is still *Pergament* and *pergamena* in Italian). Pliny the Elder, *Natural History* 13.17. The tale of Aristophanes of Byzantium (257–180 B.C.), who succeeded Eratosthenes as Librarian, dates from the second century as well.

Zoilus (7.praef.8)

Apparently Vitruvius is referring to Zoilus of Amphipolis (later fourth century B.C., not contemporary with the period of this story), Cynic philosopher, pupil of Anaximenes, noted for his bitter attacks on Isocrates, Plato, and especially Homer.

For no one (7.praef.9)

The translation, for reasons of clarity, departs more than usual from Vitruvius's own syntax.

Agatharchus [in Athens] (7.praef.11)

Agatharchus of Samos (c. 490–c. 415), collaborator with Aeschylus (c. 468–456), has been credited with the invention of something very like linear perspective. The nature of his invention is still debatable, but his generation was contemporary with developments in pictorial rendering of space, such as shadows and modeling, and a sort of deep landscape space rendered in vertical perspective that has been attributed primarily to Pythagoras of Samos. Agatharchus is presumably the same painter who was kidnapped by the wealthy, disdolute Athenian Alcibiades c. 420 to decorate his house.[1]

Silenus, Theodorus . . . et al. (7.praef.12)

The following is a highly significant list of architects, most of them well attested by other ancient authors. Silenus (writing on Doric symmetries) is otherwise unknown, as is his date. Theodorus is usually associated with Rhoecus, who was possibly his father, as one of the architects of the great Heraion of Samos (c. 560 B.C.).[2] Rhoecus is one of the great hero-inventors of early Greek history, credited with bronze casting (i.e., lost wax), the set square, lever, lathe, lock and key.[3] The reason that Vitruvius calls the temple Doric is that in its incomplete state, completed to the cushions of the capitals but without the volutes, it may have looked like a Doric type with an egg-and-dart echinus. The works of the following architects are well attested by remains: Pytheos and the temple of Athena at Priene (c. 340) and, with Satyrus, the Mausoleum at Halicarnassus; Ictinus and Carpion of the Parthenon ("Minerva") at Athens; Theodorus of Phocaea and the Tholos at Delphi (c. 380–370 B.C.), Philo, architect of the porch of the Telesterion at Eleusis (7.praef.17) and the Arsenal in Piraeus;[4]

1 Plutarch, *Alcibiades* 17.

2 Herodotus 60; Pausanias 8.14.8; Diodorus Siculus 1.98.5–9; Diogenes Laertius 2.103.

3 Pliny the Elder, *Natural History* 7.198.

4 The Arsenal is known through a meticulous inscribed building contract or description, *Inscriptiones Graecae* 2^2, as is also the porch of the Telesterion, *IG* 2^2 1666, referred to in 7.praef.17. See J. J. Coulton, *Greek Architects at Work* (London and Ithaca, 1977), 55.

Hermogenes and the temples of Artemis (Diana) at Magnesia and Dionysos (Father Liber) at Teos.[5] Arcesius (possibly fourth century B.C. is known only through Vitruvius (also 4.1.1 as a detractor of Doric).

The nature of these publications on "symmetries" is debatable. Many must have been essentially technical descriptions, perhaps very similar to the Prostoon inscription of Eleusis and the Arsenal inscription,[6] although others must have expressed broader opinions (such as Pytheos's assertions that the architect should master all of his constituent disciplines).

Leochares, Bryaxis, Scopas,
Praxiteles, Timotheus (7.praef.13)

Vitruvius lists acknowledged major sculptors of the mid- or later fourth century B.C. Leochares (fl. c. 372–320 B.C.); Bryaxis (second half of the fourth century); Scopas of Paros (mid-fourth century, also architect of the temple of Athena Alea at Tegea); Praxiteles (c. 400–330/325 B.C.); Timotheus, also sculptor of the temple of Asclepius at Epidaurus (c. 375 B.C). On the collaboration of these on the Mausoleum, see Pliny the Elder, *Natural History* 36.30.

Nexaris, Theocydes . . . (7.praef.14)

This is a list of artists who, like Polycleitus, wrote on symmetries. Surviving manuscripts of Vitruvius are inconsistent in spelling Greek names, sometimes using Greek -os, sometimes Latin -us. The translation follows the manuscript. Nexaris, Theocydes, and Sarnacus are otherwise unknown. Demophilus, possibly Demophilus of Himera (first half of the fifth century B.C.); Pollis, probably a sixth-century bronzeworker; Leonidas, painter (fourth century B.C.); Silanion, Athenian bronze sculptor (fourth century B.C.); Melampus, unknown, unless identified as Melanthios, painter of the school of Sicyon and author of a treatise;[7] Euphranor of Corinth (c. 395–330/325), painter, sculptor, and author of a treatise on symmetries.[8]

Diades, Archytas, Archimedes, Ctesibios,
Nymphodorus, Philo of Byzantium, Diphilos, Democles,
Charias, Polyidos, Pyrrhos, and Agesistratos (7.praef.14)

Again, Vitruvius spells Greek names inconsistently, sometimes with the Greek ending -os and sometimes with the Latin ending -us. The translation follows manuscript tradition in observing the inconsistency. Polyidos, engineer of Philip II, and his students, Diades and Charias, engineers of Alexander, laid the foundations of advanced siegecraft in the later fourth century B.C.; Diades's treatises were probably the core of the material later developed by Philo of Byzantium and Vitruvius's contemporary Athenaeus. Agesistratos may be the joint source for both Vitruvius (10.13–15) and Athenaeus. Archytas of Tarentum (c. 460–365), Archimedes, and Ctesibios are among the best known mathematicians/engineers. Nymphodorus, Diphilos, and Democles are otherwise unknown. Pyrrhos, king of Epirus (319–273 B.C.), was one of the boldest military campaigners of Greek antiquity and an author of a treatise on siegecraft.

Fufi[ci]us, Terentius Varro, Publius Septimius (7.praef.14)

Fufius, or Fuficius, is otherwise unknown. M. Terentius Varro (116–27), was an encyclopedic polymath, author of *De lingua latina* and an encyclopedia of the liberal arts, *De novem disciplinae,* which included architecture and medicine. P. Septimius is otherwise unknown, but may be Vitruvius's source for the teachings of Hermodorus of Salamis and hence possibly also for the symmetries of Hermogenes, who is not included in this list.[9]

Antistates, Callaeschros, Antimachides,
Pormos (Porinos), Cossutius (7.praef.15)

The first four personages on Vitruvius's list are otherwise unknown, but apparently the original architects of the colossal Olympieion of Athens, begun but left unfinished by Pisistratus, tyrant of Athens (566–528 B.C.), and continued as a Corinthian dipteros by Antiochus IV (175–164) with the Roman architect Cossutius. This Cossutius is very likely a member of a large family of architect-entrepreneurs from Campania.[10]

Ephesian Diana . . . Milesian Apollo (7.praef.16)

The Cretans Chersiphron and his son Metagenes were presumably the architects of the first Artemision of Ephesus, which, according to Pliny the Elder (*Natural History* 16.213; 36.95), took 120 years to complete (c. 560–440?). The "completion," by the temple slave Demetrius and by Paeonius of Ephesus, must be the reconstruction after the temple was burnt in 356 B.C. (supposedly on the night on which Alexander the Great was born, by an arsonist who wanted his name to be immortal). Alexander contributed funds to the rebuilding after his victory on the Granicus in 334. The colossal Ionic dipteral temple of Apollo at Didyma outside Miletus was, along with the great dipteroi of Samos and Ephesus, built in the first half of the sixth century B.C.; it was burnt in the Ionian revolt of 494, and rebuilt presumably after Granicus, with Paeonius and Daphnis of Miletus as architects, the latter of whom is otherwise unknown.

Demetrius of Phaleron (7.praef.17)

An intellectual, the Macedonian puppet ruler of Athens (317–307), he supposedly assisted in the foundation of the Library of Alexandria.

5 Pater Liber is an ancient Italic god of vegetation, and hence was assimilated to Dionysos/Bacchus. The temple is not a monopteros but a peripteros.

6 *IG* 2^2, 1666, 1668; J. Bundgaard, *Mnesicles, A Greek Architect at Work* (Copenhagen, 1957), 97–98, 117–132; K. Jeppesen, *Paradeigmata* (Aarhus, 1958), 69–101, 109–131; discussion in J. J. Coulton, *Greek Architects at Work* (Ithaca and New York, 1977), 54–55.

7 Pliny the Elder, *Natural History* 35.50; Diogenes Laertius 4.18.

8 Pliny the Elder, *Natural History* 35.129.

9 P. Gros, "Hermodoros et Vitruve," *Mélanges de l'Ecole Française de Rome. Antiquité* 85 (1973), 137–161.

10 E. Rawson, "Architecture and Sculpture: The Activities of the Cossutii," *Papers of the British School at Rome* 43 (1975), 36–37.

the enormous cella of Ceres and Proserpina at Eleusis (7.praef.16)

The Telesterion of Demeter and Korê (Proserpina) at Eleusis.

G. Mucius; Marius's Temple to Honor and Battle-courage (7.praef.17; also 3.5.2)

G. Marius's temple of Honos et Virtus was built in 101 B.C. from the *manubiae* (spoils) of G. Marius's victories over the Cimbri and the Teutones; the site is unknown but possibly near the Capitol or the Velia. Vitruvius mentions it earlier (3.5.2) along with the temple of Jupiter Stator in the Porticus Metelli, designed by Hermodorus of Salamis, as an example of a temple *sine postico*. G. Mucius may have been a client/freedman of the "anti-Hellene" Q. Mucius Scaevola Augur (speculating from the name alone) and a student of Hermodorus; his significance may be that he tried to adapt Greek symmetries to traditional Italic plans.[11]

nails (7.1.2)

Hand-wrought iron nails were cheap and plentiful by the first century B.C.

dodrans (7.1.3)

Three-quarters foot = three palms = one span.

hexagons (7.1.4)

Literally, "honeycombs."

Tiburtine herringbone tile work (7.1.4)

Testacea spicata tiburtina, Tiburtine herringbone terracotta, called *opus spicatum* by modern archaeologists. The term derives from Latin *spica*, an ear of grain, whose interlocking seed husks also show a herringbone pattern.

slope of two digits for every ten feet (7.1.6)

1:80; cf. 8.7.1, for slope of aqueducts 1:250.

herringbone terracotta [blocks] (7.1.7)

Spica testacea.

plasterwork (7.2.1)

The translation follows the sequence: *trullissatio* = rough plastering; *tectorium* = plaster (suitable for painting); *albarium* = stucco, with the connotation that stucco can be molded.

the machines (7.2.2)

Presumably scaffolding (cf. 10.1.1).

plastered as roughly as possible (7.3.5)

This means leaving a rough surface to assist in the adhesion of the next layer.

plaster floats (7.3.7)

Reading with the MSS as *liaculorum*. Tertullian uses the word *lio*, to level.

moist plaster (7.3.7)

The fresco layer.

horsetails (7.3.11)

The bryophyte *equisetum*, which is strong enough to go into mud.

footed tiles (7.4.2) (Figure 103)

Reading the MSS either as *mammatae* (nippled) or *hamatae* (hooked).

beginnings of painting
[polished] plaster (7.5.1) (Figures 104, 105)

Vitruvius's description gave rise to modern scholars' distinction of four styles in Pompeiian wall painting.[12]

Tralles . . . Apaturius of Alabanda (7.5.5)

Tralles and Alabanda are both in western Asia Minor. Apaturius and Licymnius (or Lykinos) are otherwise unknown, but the story probably dates from the second century B.C. or later because it is probable that this is when this kind of fantasy architecture (i.e., the basis of the second and third Pompeiian styles) was developed in real and painted architecture in Alexandria.[13] An ekklesiasterion is a council house that supposedly can hold the entire citizen body of a town.

four sextarii (7.8.2)

One sextarius = c. 0.5461 l.; 6 sextarii = 1 congius; 16 sextarii = 1 modius.

shining (ganôsis) (7.9.3–4)

This is apparently a final polishing, not to be confused with encaustic, painting in hot wax.

the temples of Flora and Quirinus (7.9.4)

The temple of Quirinus (Doric dipteral, according to 3.2.7; restored by Augustus in 16 B.C.) was near or on the Alta Semita on the west edge of the Quirinal hill. The temple of Flora was also on the hill or in the valley below, outside the Servian walls. The cinnabar workshops may have been in an industrial quarter just outside the walls.

Vestorius (7.11.1)

A wealthy banker and innovative entrepreneur of Puteoli, known to Cicero and Atticus.[14] Puteoli was and remained the principal port for the Egyptian grain fleet in Italy until the

11 P. Gros, "Les premières générations d'architectes hellénistiques à Rome," *L'Italie préromaine et la Rome républicaine, Mélanges J. Heurgon* (Rome, 1976), 407.

12 Especially see A. Mau, *Geschichte der dekorativen Wandmalerei in Pompeii* (Berlin, 1882).

13 J. R. Clarke, *The Houses of Roman Italy* (Berkeley, 1991), 45; J. McKenzie, *The Architecture of Petra* (Oxford, 1990), 85–100.

14 Cicero, *Ad Atticum* 14.9.1; 14.12.3.

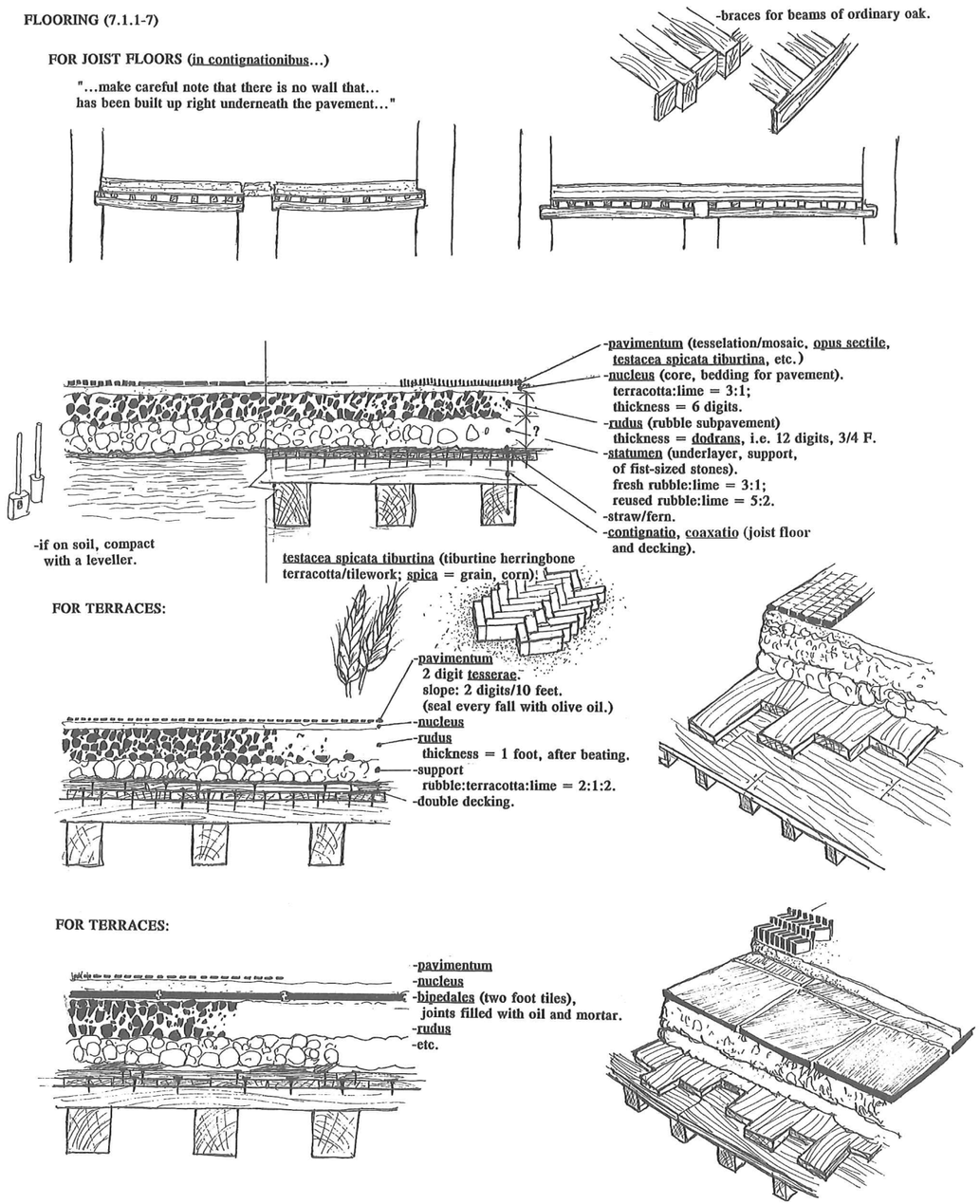
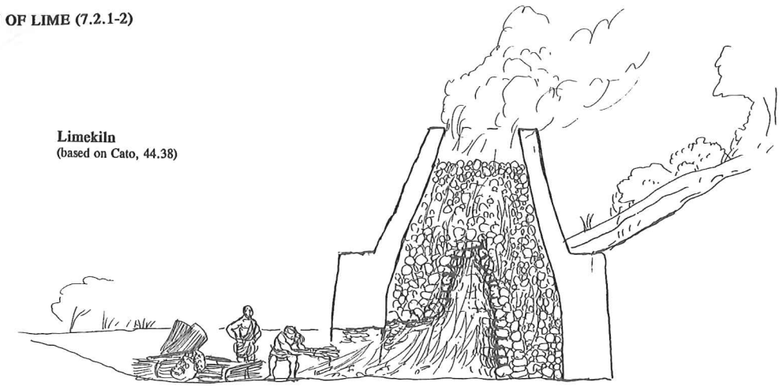


Figure 100. Flooring (7.1.1–7).

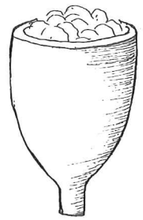
PREPARATION OF LIME (7.2.1-2)

Limekiln
(based on Cato, 44.38)



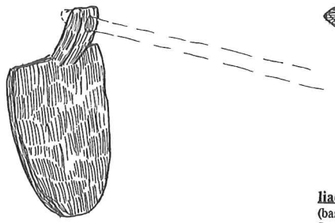
Slaking lime

From the column of Trajan



Half amphora for transport of calx viva

ascia (hoe)
(based on object found in the House of the Skeleton, Pompeii)



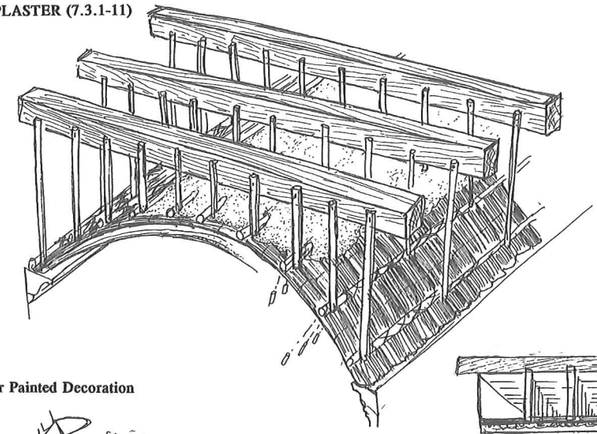
trowel (based on object in the Saalburg Museum)

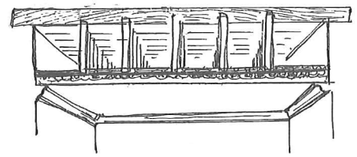
liaculum (plaster float)
(based on object in the Saalburg Museum)

Figure 101. Preparation of Lime (7.2.1–2).

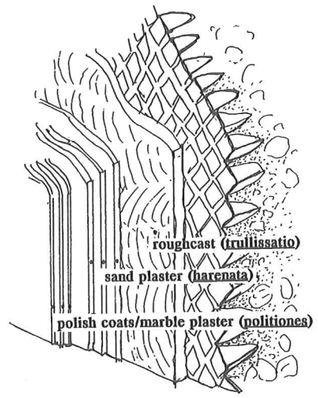
CEILINGS AND WALL PLASTER (7.3.1-11)

Suspended Ceilings

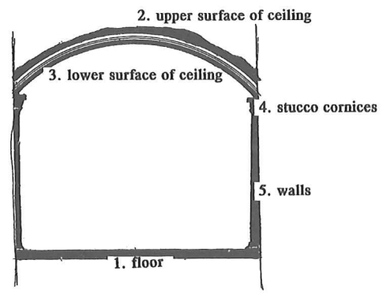




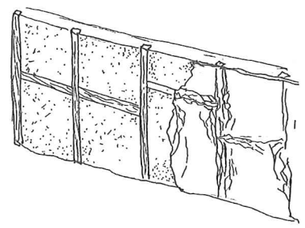
Plaster (tectorium) for Painted Decoration



Finishing Sequence



Plaster on opus craticium



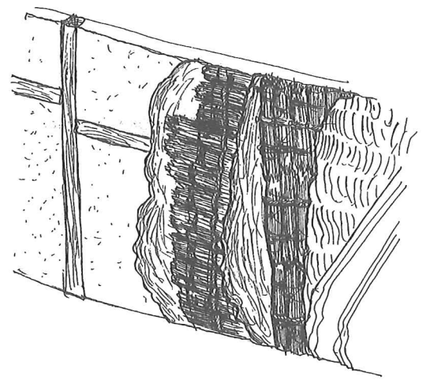


Figure 102. Ceilings and Wall Plaster (7.3.1–11).

PLASTERWORK IN DAMP LOCATIONS (7.4.1-3)

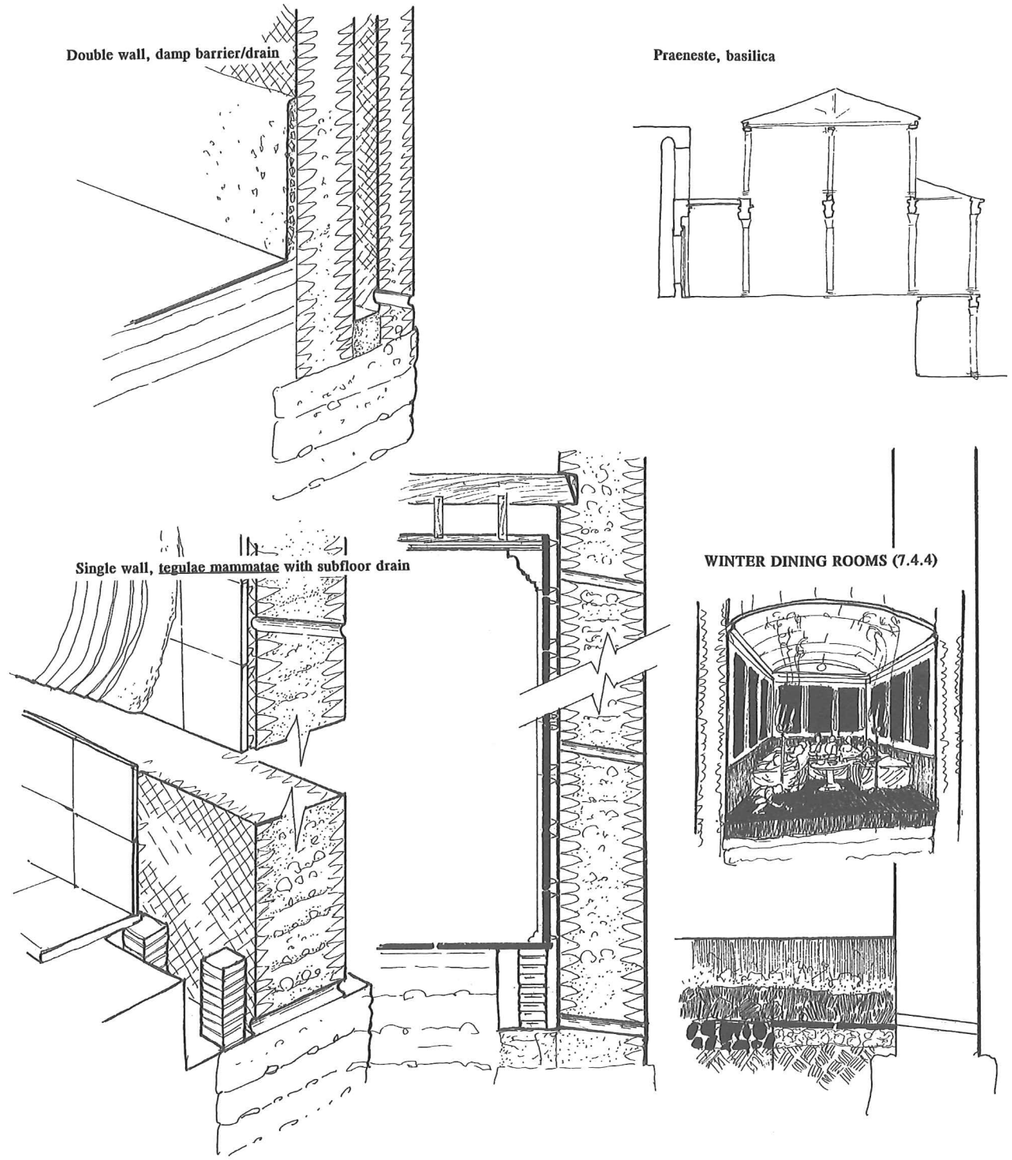


Figure 103. Plasterwork in Damp Locations (7.4.1–3).

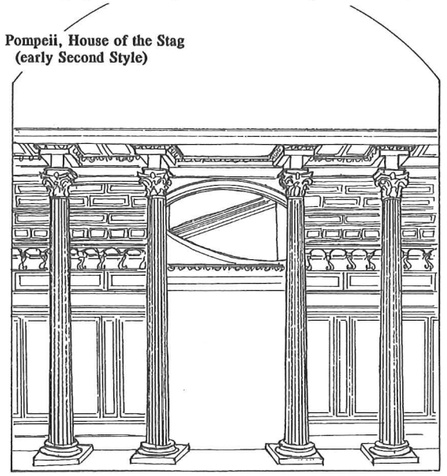
STYLES OF WALL PAINTING (7.5.1-3)

Pompeiian First Style: "...imitated the varieties and placement of marble veneers..."

Pompeii, House of Sallust, c. 100 B.C.
[after Mau, Geschichte der dekorativen Wandmalerei in Pompeii (Berlin, 1882), pl. 2A.]

Pompeiian Second Style: "...later...also imitated the shapes of buildings and the projection into space of columns and pediments..." (c. 100 B.C.)

Pompeii, House of the Stag
(early Second Style)



Pompeii, House of the Cryptoporticus
(later Second Style)

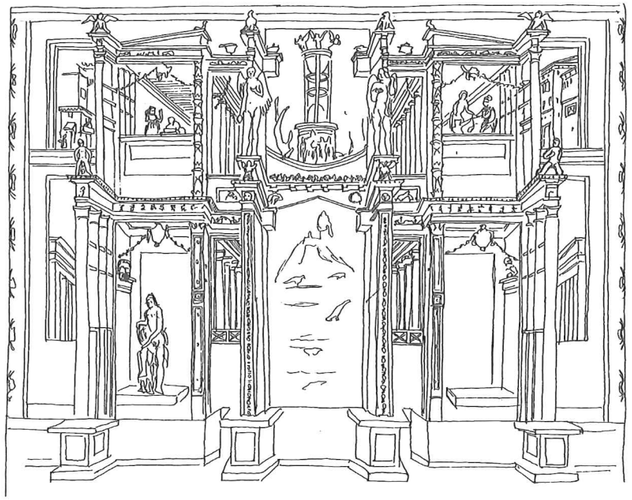
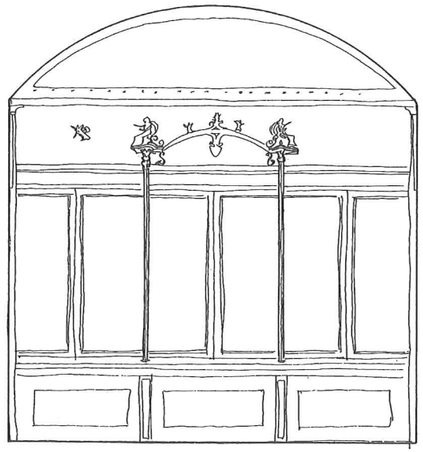


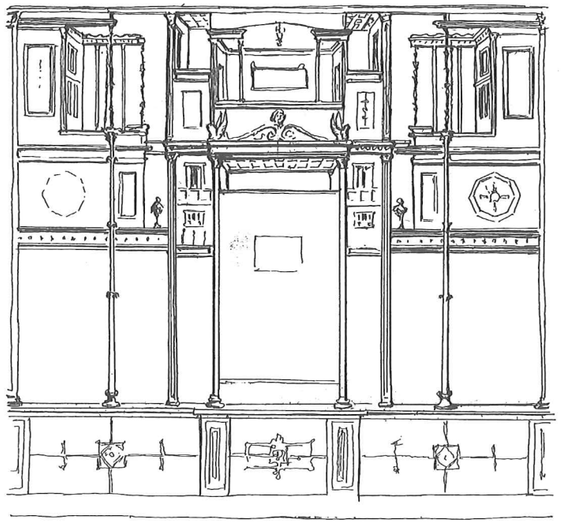
Figure 104. Styles of Wall Painting: Pompeiian First and Second Style (7.5.1–3).

STYLES OF WALL PAINTING (7.5.1-3)

Pompeiian Third Style: "...monsters are now painted in frescoes..."



Pompeii, House I.11.12, early Third Style



Pompeii, House V.1.14, late first century B.C.
[after Mau, Geschichte der dekorativen Wandmalerei in Pompeii (Berlin, 1882), pl. 2A.]

Figure 105. Styles of Wall Painting: Pompeiian Third Style (7.5.1–3).

early second century A.D., when it was displaced by the Trajanic harbor at Ostia.

kermes (7.14.1)

Quercus coccifera, a shrub oak whose fruit produces a crimson dye.

weld (7.14.2)

Reseda luteola, a swamp plant used to make yellow dye, also known as dyer's rocket, yellowweed, or dyer's mignonette. Pliny the Elder, *Natural History* 33.87, 91.

woad (7.14.2)

Isatis tinctoria, also called dyer's weed (as are several other plants), a blue dye superseded by indigo.

BOOK 8

Heraclitus, Euripides, Anaxagoras . . .
Pythagoras, Empedocles, Epicharmos (8.praef.1)

This is another list of the formulators of the fundamental theories of natural philosophy. Euripides is the playwright of the later fifth century, Empedocles (fl. c. 444 B.C.) is the figure normally credited with formulating the definitive form of earth-air-fire-water chemistry. Again Vitruvius is inconsistent in his spelling of Greek names.

definite limits in the direction of those regions (8.1.1)

The vocabulary here is much the same as that for laying out a *templum* in augury.

underground channels (8.1.6)

This method of collecting water from several weak wells sounds very much like a Persian qanat, although there are some systems in Rome that consist of mazes, *cuniculi*, which appear to function as seepage collectors.[1]

the earthly globe (8.2.6)

Vitruvius's discussion is contemporary with M. Vipsanius Agrippa's world map in the Porticus Vipsania and may be informed by it.

the Nile (8.2.6–7)

This idea that the Nile rises in the West (Mauretania) and flows underground, reemerging in the Sudd, goes back at least to Herodotus (2.28–34), who presents a slightly different theory about how it may flow from the West.

Camenae, Aqua Marcia (8.3.1)

The spring of the Camenae is located on the south side of the Caelian Hill. The Aqua Marcia was completed in 144 B.C. and thought to be the best of the aqueducts.

1 In the Horti Aciliani and the Forte Antenne (ancient Antemnae). I. Riera, in I. Riera ed., *Utilitas Necessaria: Sistemi idraulici nell'Italia romana* (Milan, 1994), 330.

sweet-water springs (8.3.1)

Taking *dulcis* to mean good-tasting water, although it may simply mean fresh water as opposed to salt or brackish.

the river Albula (8.3.2)

The source of the Albula outside Tivoli is at the travertine deposits, and the functioning baths there still emit a strong sulphurous smell.

push the force of their gusts; sources of springs at the same height as these hillocks (8.3.2–3)

This discussion of the force of springs depends on Empedoclean chemistry (wind as the result of a collision of heat and water) rather than a concept of a pressure head.

This water has an appearance (8.3.6)

Aquae here is not a genitive but a dative of possession; *species* in this case can not be a term of classification.

type of water (8.3.6)

Vitruvius here uses *genus aquae*, not *species*.

wine . . . of Lesbos, and so on (8.3.12)

This is a list of the best known ancient wines. Maeonia is in the upper Hermos valley in western Asia Minor, Lydia in north-central western Asia Minor. Falernian of Campania had the reputation as being among the best of ancient wines.

the inclination of the firmament (8.3.13)

This is another reference to the scientific theory that all terrestrial diversity is generated by the oblique rotation of the celestial spheres, particularly the sun.

Juba (8.3.24)

Presumably Juba II, son of Juba I, who as a child was led in Caesar's triumph of 46 B.C. Given Roman citizenship by Octavian, he was reinstated as a client king in Numidia and, in 25 B.C., in Mauretania. He was a man of considerable learning and wrote many books on geography, history, language, and natural philosophy.

Africa is the mother and nursemaid of wild beasts (8.3.24)

This phrase is similar to Horace *Odes* 1.22.15–16, published in 23 B.C., but it also may be lifted from the *Libyka* of Juba, published in 26/25 B.C.

Gaius Julius, the son of Masinissa (8.3.25)

The identification of this person is uncertain, but presumably he was a scion of the royal house and descendant of Masinissa, king of Numidia and client of Rome until his death in 148 B.C. The name and the information Vitruvius gives indicates he may have been awarded Roman citizenship as a reward for service with Caesar.

Theophrastos, Timaeus, Posidonios, Hegesias, Herodotus, Aristides, and Metrodorus (8.3.27)

Again, Vitruvius's spelling of Greek names is inconsistent. Theophrastus, pupil and successor of Aristotle at the Lyceum;

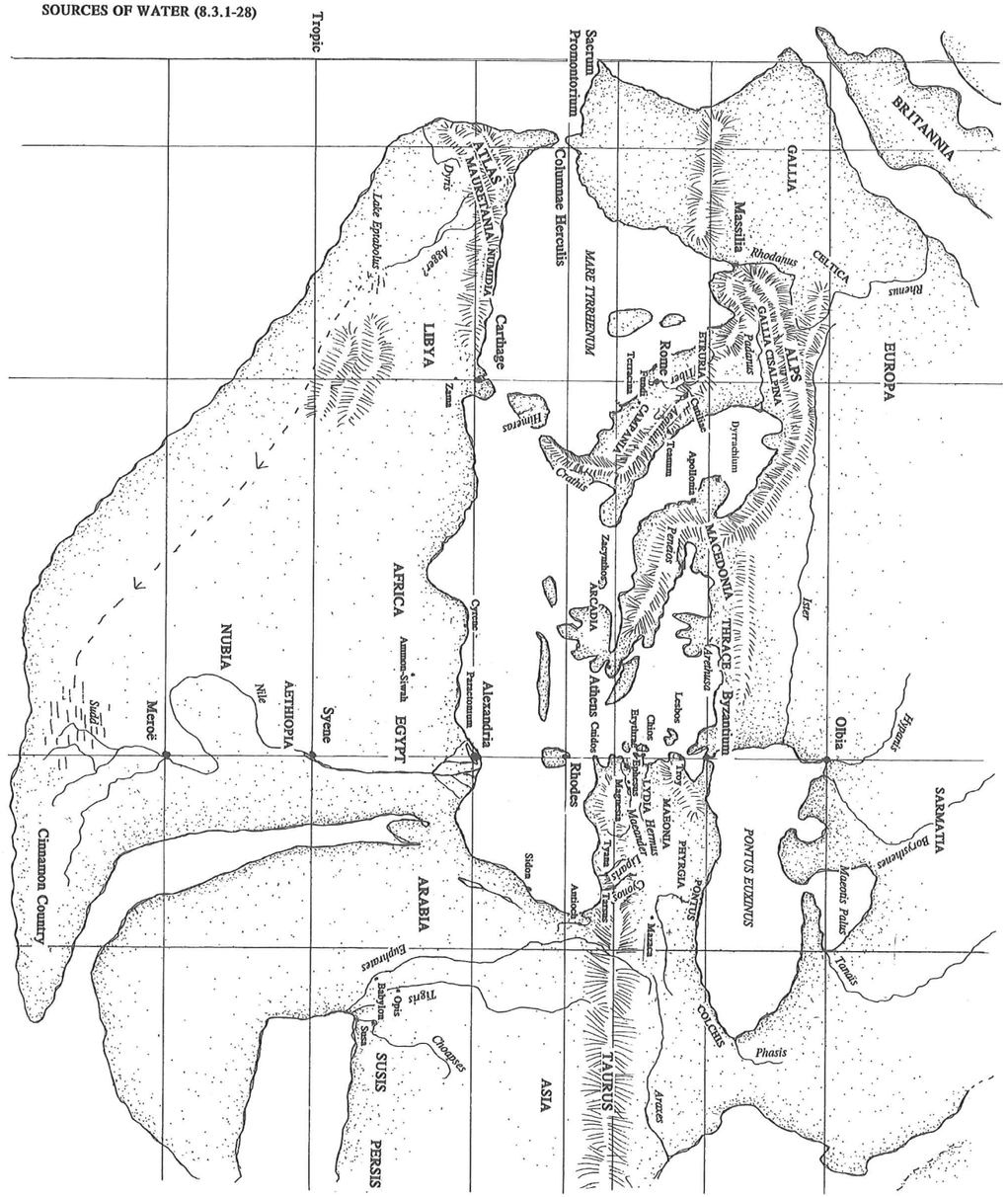


Figure 106. Sources of Water (Map of the Mediterranean World) (8.3.1–28).

Timaeus of Tauromenium (c. 346–250 B.C.), author of a history of Sicily; Posidonius of Apamea (c. 140/130–59/40 B.C.), philosopher, historian, geographer, and naturalist; Hegesias could be Hegesias of Maroneia or Hegesias of Magnesia; Herodotus (d. c. 425 B.C), the great historian of the mid-fifth century; Metrodorus of Skepsis and Aristides are uncertain.

Corinthian vase (8.4.1)

An alloy of bronze, gold, and silver (Pliny the Elder, *Natural History* 9.13.9; 34.6–9; 37.49).

diopters, or water levels, or a chorobate (8.5.1) (Figure 107)

The diopter was an instrument apparently like a modern transit or theodolite and must have had some capacity for measuring angles, probably both vertical and horizontal. As such, it also would have been serviceable as a level (although like a modern transit, it may have been less accurate as such than a dedicated level). The diopter was known to Archimedes, Hipparchus, and Ptolemy, and the most detailed description is in Hero of Alexandria.[2] (True triangulation surveying with trigonometric functions seems not to have been used in antiquity; it generally dates to the end of the sixteenth and early seventeenth centuries.) The water level is unattested in representations, but its general principle can be guessed fairly easily (see figure). The chorobate is known only through Vitruvius (it is not mentioned in the *Corpus agrimensorum*), and therefore it may have been an unusual instrument and a personal recommendation of Vitruvius.

fit together by hinges (8.5.1)

This implies that, like any surveying instrument, the chorobate could be dismantled and transported.

Archimedes' books will say that there
cannot be a true leveling by means of water (8.5.3)

Although in a way Archimedes is right (the course of the water in a water channel follows the curvature of the earth), Vitruvius is also right to note that in functional circumstances the curvature is insignificant, and what counts is the relationship between the two ends of the water vessel, which when level are tangent to the earth's curvature.

slope . . . no less than half a foot every hundred feet (8.6.1)

There are two possible readings of the MSS here: *sicilicos* or a quarter of an inch per 100 F, or a slope of 1:4,800; or *semipede*, a half foot, or a slope of 1:200. The range of the slope in Roman aqueducts varies greatly, normally from 1:150 to 1:2,900 (with an extreme in the aqueduct of Nîmes at 1:14,000), and sometimes within a single aqueduct (the aqueduct of Gier varies from 1:151 to c. 1,000, that at Basse-Fontaine from 1:59 to 1:2,500).[3]

1:200 seems steep, but immediately above (8.5.3) Vitruvius says that "If a slope is great, the current of the water will be easier to manage," and in 7.1.6 Vitruvius recommends a slope of two digits (one-eighth foot) for every ten feet for open-air floors (slope of 1:80).

castellum aquae (8.6.1) (Figure 108)

A reservoir for water distribution is usually just inside the city gates at the highest point of the circuit of the walls.

those who bring water into their own homes (8.6.2)

An *actus* is 120 feet, the standard unit for measuring centuriated plots.

there is one *actus* (120 feet) between every two (8.6.3)

The illegal tapping of public mains for private homes was a major problem for Agrippa's and Frontinus's administrations.[4]

the diameter of the pipes (8.6.4)

Roman lead water pipes were made as lead sheets rolled around a form with either a folded or a soldered join. The ten standard calibers that Vitruvius recommends are measured in terms of the width of the sheet, which is in effect the circumference of the pipe plus the overlap for the join. Frontinus gives a somewhat more complicated system and attributes to Agrippa or Vitruvius the introduction of a different measure, the *quinaria*, which refers either to a five-digit sheet rolled into a pipe, or a pipe five *quadrantes* (quarter-digits) in section.[5] Vitruvius also gives the weight of each sheet, which implies that the standard wall thickness for a pipe is one-quarter inch (9.0627 m.), regardless of diameter.[6]

but if there is a very broad
valley . . . the "belly" (8.6.5) (Figure 109)

Although Vitruvius mentions inverted siphons in conjunction with a closed pipe system, they can be combined with open-channel masonry aqueducts with the siphon running from one open castellum on one side of the valley to another on the other. The economic break-even point between building a lead-pipe siphon, which required high craftsmanship and maintenance, seems to have been c. 150 feet; in valleys of less depth, aqueducts were normally carried across on masonry arches, from c. 155/160 feet to c. 375 feet, normally lead pipes with an inverted siphon.[7] The upper limit for lead siphons is the amount of pressure head that the lead pipe can sustain. The siphon at Pergamum has a pressure head at one point of c. 500 feet (250 lb./sq. in. or 18.5 kg/cm²), although it was later replaced by an open-channel aqueduct.[8]

2 C. Germain de Montauzan, *Essai sur la science et l'art de l'ingénieur aux premiers siècles de l'empire romain* (Paris, 1908), 46 seq.; A. G. Drachmann, *The Mechanical Technology of Greek and Roman Antiquity* (Munksgaard, 1963), 197–198.

3 C. Germain de Montauzon, *Les Aqueducs de Lyon* (Paris, 1909), 170; L. Callebat, ed., *Vitruve, de l'architecture*, viii (Paris, 1973), 146–148.

4 Frontinus, *De Aquis*, 112–114.

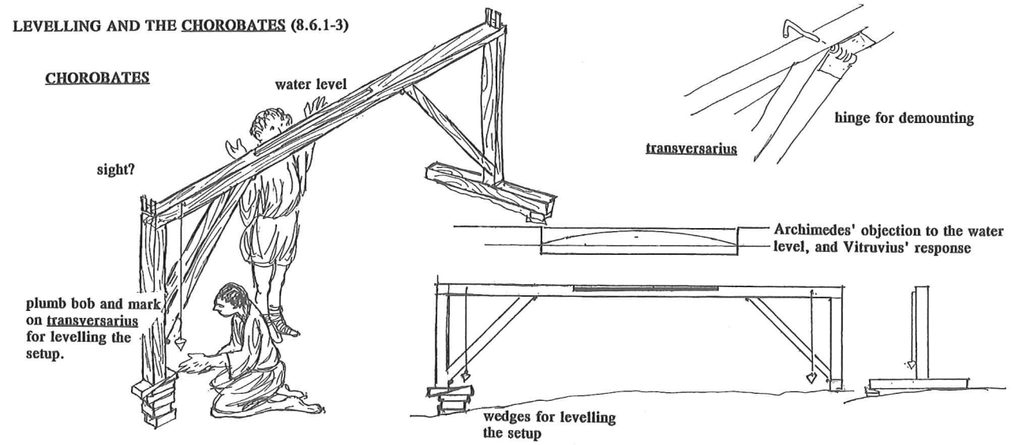
5 The system is measured in *quinarii* up to the *fistula vicenaria* (five-digit pipe), then in *digiti quadrati*, which implies a more advanced system of adjusting to accurate cross section than Vitruvius's system. Frontinus *De Aquis* 25, 26–34.

6 J. G. Landels, *Engineering in the Ancient World* (Berkeley, 1978), 42–45.

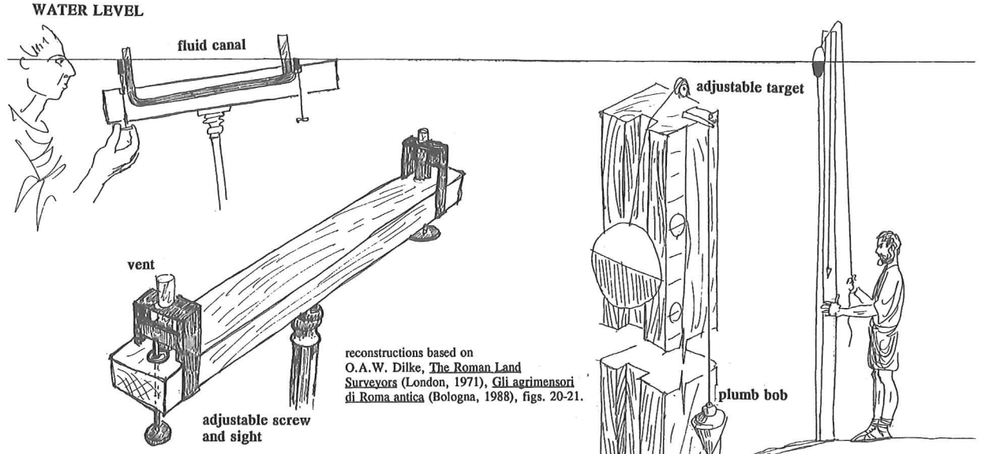
7 A. F. Norman, "Attitudes to Roman Engineering and the Question of the Inverted Siphon," *History of Technology* 1 (1976), 45–71, esp. 61.

8 Landels, op. cit., 47–49.

LEVELLING AND THE CHOROBATES (8.6.1-3)



WATER LEVEL



reconstructions based on O.A.W. Dilke, The Roman Land Surveyors (London, 1971), Gli agrimensori di Roma antica (Bologna, 1988), figs. 20-21.

LEVEL TRAVERSE

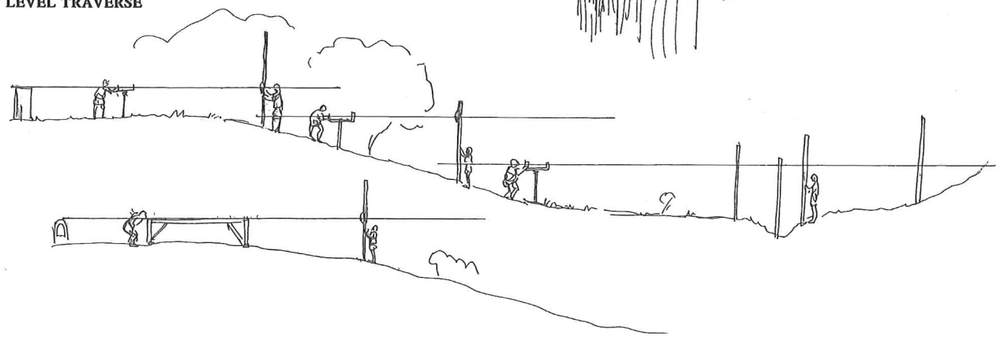
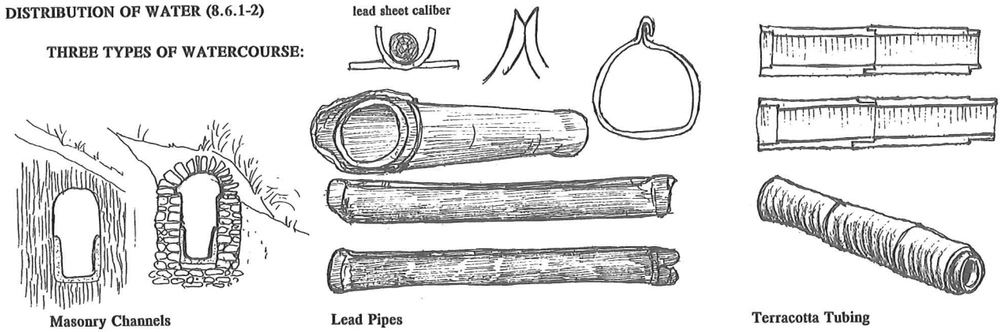


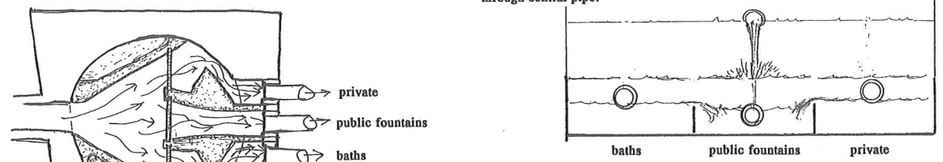
Figure 107. Levelling and the *Chorobates* (8.6.1–3).

DISTRIBUTION OF WATER (8.6.1-2)

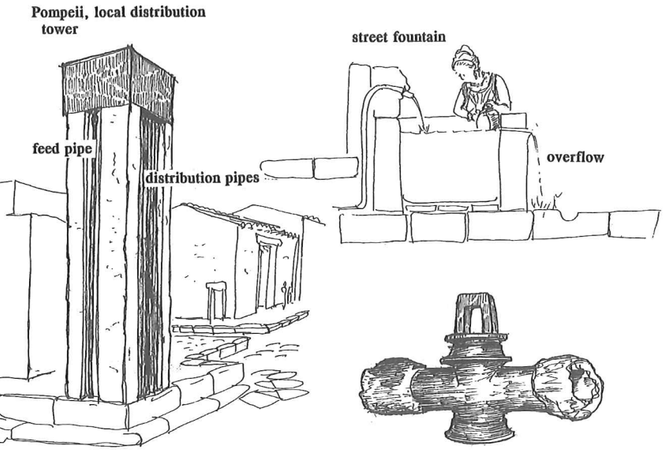
THREE TYPES OF WATERCOURSE:

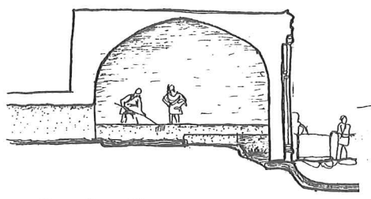


Vitruvius' scheme for a castellum aquae



Pompeii, local distribution





Pompeii, castellum aquae
[after A. Maiuri, "Pompeii. Pozzi e condutture d'acqua nell'antica città," NotSc (1931), 546-76, 555, fig. 4.; and J.P. Adam, La construction romaine (Paris, 1989²), fig. 579.]

valve, presumably from the Lago di Nemi wreck
[after F. Kretschner, Bilddokumente der römischer Technik (c. 19907), figs. 94, 95.]

Figure 108. Distribution of Water (8.6.1–2).

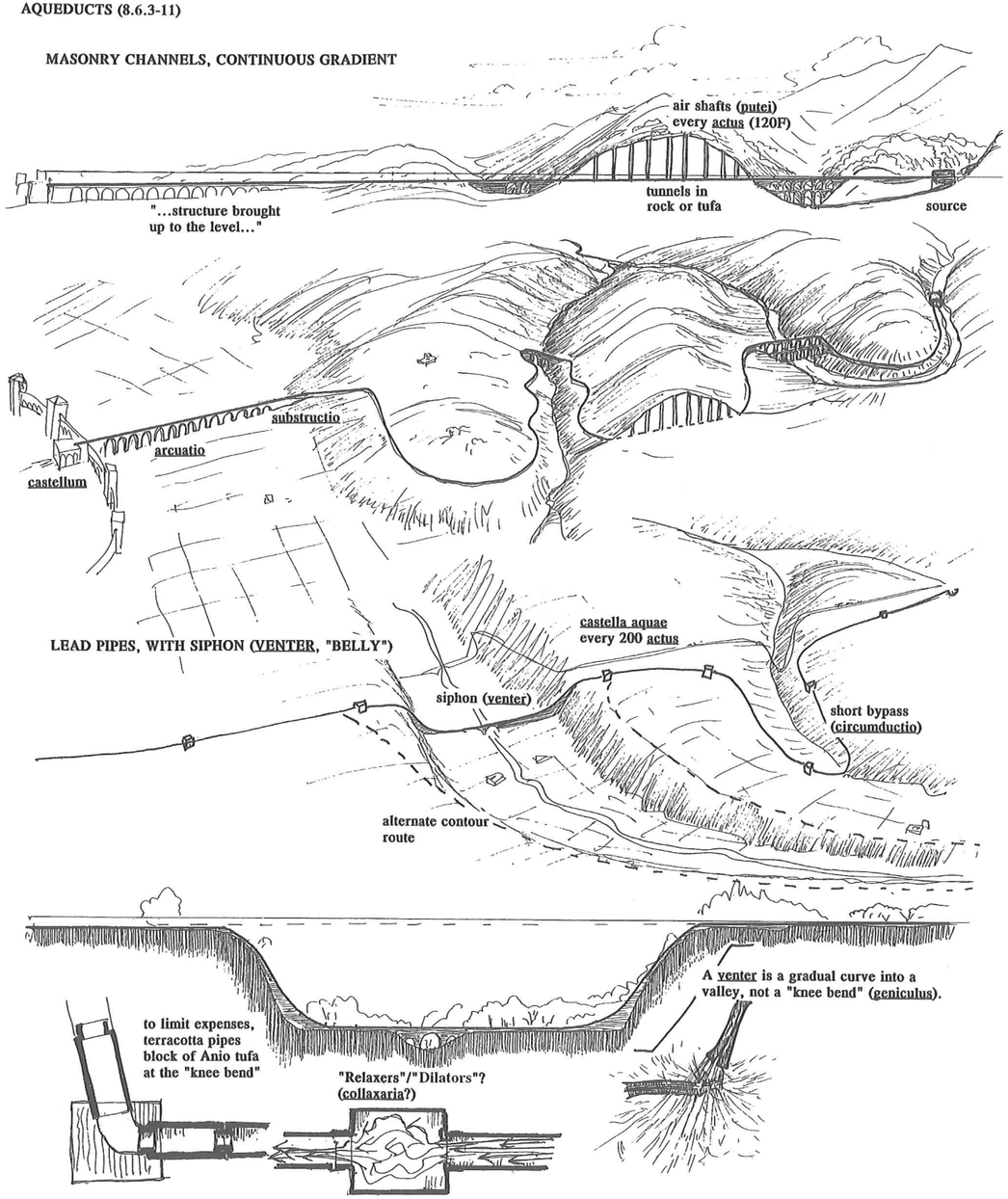


Figure 109. Aqueducts (8.6.3–11).

dilations (8.6.6)

The MSS reading *colliviaria* is much disputed. The reading proposed here, *collaxaria*,[9] implies that at the rise of the pipe some sort of expanded pipe was inserted with the belief (right or wrong) that it relaxed the pressure on the bottom of the upslope. Technically, such a device should cause the speed of the current to decrease but not necessarily the pressure.

reservoirs *[castella aquae]*
at an interval of two hundred *actus* (8.6.7)

Equivalent to 24,000 feet. Note that one does not put *castella aquae* in masonry open-channel aqueducts because this type of aqueduct cannot be shut down except at the source, and then one has to wait for the entire system to drain before one can do repair work. Frontinus points out that one can build temporary bypasses around sections of open-channel aqueducts in order to do repair work (*De Aquis*, 2.124).

lead is toxic (8.6.10)

Vitruvius is the first writer to mention lead poisoning. White lead oxide forms in water pipes. Probably most lead water pipes did not pose a serious health problem because almost all Roman water mains worked by continuous flow, and therefore the water was not in the pipe long enough to absorb much lead. The problem would be greater in off-flow pipes with spigots, where the water was static between times when the tap was opened.

opus signinum (8.6.14)

This is supposedly waterproof cement, but it is not what is commonly called *opus signinum* by modern archaeologists; this now refers to any mortar with admixture of crushed terracotta, usually intended for waterproof situations.

limed (8.6.15)

Here and in the next sentence, context demands that *calcetur* derive from *calx* "lime," and not *calx* "heel" = "trample." This usage is again a *hapax*, but not a surprising one; liming cisterns does not occur in Latin literature. For the formation of the word, compare *statuminetur* at 7.1.3.

BOOK 9

illustrious athletes . . . same
honors . . . are not bestowed on writers (9.praef.1)

In several of the Greek games, prizes were awarded to authors as well as athletes. Augustus created the *Ludi Actiaci* after Greek fashion, and there were six *ludi* for which the aediles and praetors commissioned plays. Poets received prizes by the later first century A.D.

9 *Collaxo* appears in Lucretius, 6.233.

Milo of Croton (9.praef.2)

Recognized as one of the greatest athletes of antiquity, six-time victor at the Olympic Games (later sixth century B.C.).

useful findings of Plato (9.praef.4) (Figure 110)

Vitruvius recasts an anecdote in Plato, *Meno* 82b–85b, where Socrates coaxes an ignorant slave to deduce the principle of doubling the square. This kind of exercise is similar to land calculation exercises in the agrimensorial treatises (e.g., Columella, *De Agricultura* 2.8–9).

the type of number that cannot
be found by means of calculation (9.praef.4)

All "*numeri*" are rational in the Vitruvian lexicon, that is, a ratio of positive integers (1/2, 15/17, etc.). Functions like pi and the diagonal of a square ($\sqrt{2}$) are irrational, and hence not "numbers."

bottom of the page (9.praef.5)

Vitruvius refers here to one of the eleven drawings originally included in his text; manuscripts preserve none of them.

Pythagoras . . . demonstrated
a set square (9.praef.6) (Figure 110)

The Pythagorean theorem is represented by the discovery of the 3-4-5 right triangle.

Archimedes; Hieron (9.praef.9)

Cf. 7.8.3 on specific gravity. Hieron II was tyrant of Syracuse (270–215 B.C.).

one sextarius (9.praef.11)

Equivalent to c. 0.546 liter.

Archytas of Tarentum and Eratosthenes of Cyrene; what
Apollo had ordered . . . at Delos; the mesolabe
(9.praef.13–14)

Archytas (first half of fourth century), and Eratosthenes (284–204), librarian of Alexandria and correspondent of Archimedes, were both mentioned earlier (1.1.18; 7.praef.14; 1.6.9). For the calculation of the mesolabe based on the solution of two mean proportionals, see figures.

Democritus . . . in which he uses
a signet ring to mark (9.praef.15)

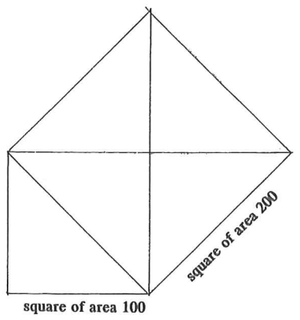
The text here may be corrupt, but Soubiran's interpretation at least corresponds to Vitruvius's respect, in the tradition of Lucretius, for crediting direct observation.

Accius (9.praef.16–17); Lucretius; Cicero; Varro (9.praef.17)

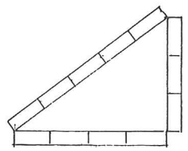
Reference to L. Accius (c. 140 B.C.–c. 90 B.C.). T. Lucretius Carus (c. 94–c. 55 B.C.), M. Tullius Cicero (106–42 B.C.), and M. Terentius Varro (166–27) are older contemporaries of Vitruvius and probably his strongest intellectual influences; directly or indirectly he cites the *De rerum natura* of Lucretius, *De oratore* of Cicero, and *De lingua latina* and the *Disciplinarum libri ix* of Varro.

USEFUL INNOVATIONS OF MATHEMATICS (9.Praef.1-14)

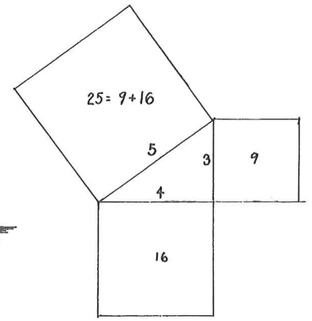
Doubling the square by geometric means, attributed to Plato



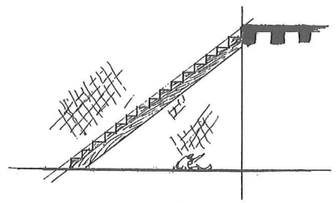
The Pythagorean Theorem: creating a 3-4-5 right triangle



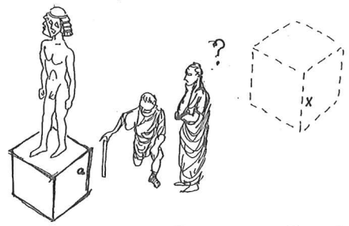
the square of the hypotenuse equals the sum of the squares of the sides



Using the 3-4-5 right triangle to dimension the components of a stair

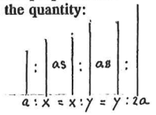


The Delian Problem: Doubling the Cube
a = side of original cube, a^3 = its volume.
x = side of cube of twice the volume, x^3 = its volume
what is the relation of x to a so that $2a^3 = x^3$?



Problem as formulated by Hippokrates of Chios in terms of finding the two mean proportionals between a quantity and twice the quantity:

$a/x = x/y = y/2a$
$x^2 = ay$, $y^2 = 2ax$
$x^4 = a^2y^2 = 2a^3x$
$x^3 = 2a^3$



The Mesolabe of Eratosthenes of Cyrene

Frame holding three identical sliding frames, each with a diagonal string. Right end of diagonal of large frame is probably moveable.
-find a:x as x:y as y:2a.
-fix left frame.
-by experimental adjustment, slide middle and right frames, and long diagonal, so that long diagonal bisects JK (at M), and so that the diagonal of each sliding frame intersects the intersections of the long diagonal and the vertical right edge of the preceding frames (at N and O).
-by similar triangles (i.e. MNK, NOG, OAC):
MK/NG = NG/OC = OC/AD;
-Hence NG and OC are the mean proportionals between MK (= a) and AD (= 2a).
(The Mesolabe can produce mean proportionals between any two quantities; a/2a is only one case.)

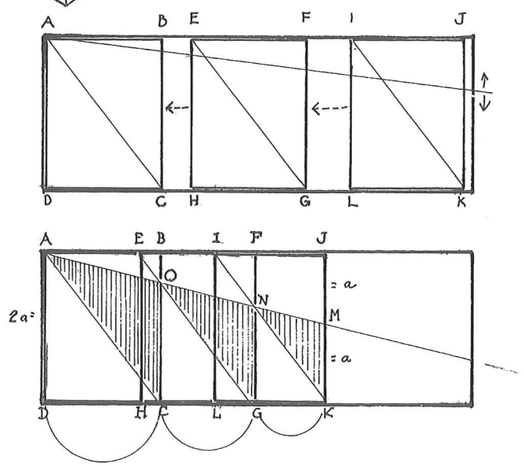


Figure 110. Useful Innovations of Mathematics (9.praef.1–4).

shadow cast by a gnomon at the equinox (9.1.1)

The normal method after Eratosthenes of measuring and recording latitude was the equinoctial shadow, not the solstitial; on that day the angle cast by the gnomon is equivalent to the latitude (angle = $\tan^{-1}$ shadow of gnomon/height of gnomon). Once one knows the size of the earth (or the length of a degree) one can use this kind of measure to calculate any N–S location where one has measured the equinoctial shadow. Eratosthenes also created a table of equinoctial shadows relative to latitude. Vitruvius may be quoting Eratosthenes' table in 9.1.1, or at least its format. This was in effect the first step toward the establishment of mathematical trigonometry because it recorded the ratio of length of shadow to height of gnomon (i.e., the tangent) for each latitude.[1] Placentia (Piacenza) is in this list because its latitude is a few minutes off 45° (45° 03′), and hence its ratio is expressed as 1:1.

in the southern half the axis is set low
and obscured by the earth (9.1.3) (Figure 4)

This is a reference to the "never-visible circle" of celestial astronomy, the amount of the celestial sphere that is obscured by the earth and dependent on the viewer's latitude (i.e., at the poles one sees 90° of the firmament, at the equator, with the rotation of the earth, all of it, at 45° N one sees everything down to 45°S. See figures for Book 1).

broad circular belt . . . with twelve signs (9.1.3)

Reading *lata* rather than *delata*. Because Vitruvius never uses the term *zodiac*, it has been avoided here. Hyginus (second century A.D., not the *gromaticus* or Augustus's librarian) and Ptolemy (second century A.D.) use *zodiac*, a term of Greek derivation (*zoôn* = animal).

each sign shows an image taken from nature (9.1.3)

Vitruvius makes the constellations obey his precepts for good art (7.5.3–4). Manilius (*Astronomica* 1.456, slightly later than Vitruvius) tells his readers that the images of the constellations are not completely outlined with stars because the heavens could not withstand so intense a conflagration.

above the earth (9.1.4) (Figure 111)

That is, above the equator. Only in the night sky do the signs of the Zodiac appear to climb and fall with the seasons.

stars of Mars and Jupiter (9.1.5)

The phrase "star of" expresses the idea that the names of the planets refer to gods but are not identical with them.

Just as the stars of Mercury and Venus
are completing . . . their journeys . . . they
regress; [t]he sun's rays stretch out into the
universe . . . form of a triangle (9.1.6–13) (Figure 112)

Vitruvius provides two explanations for retrograde motion. The first is conventional, that Mars and Venus orbit around the sun's rays, but the other is unusual because it relies on an application of Empedoclean chemistry (i.e., the attractive power of heat), and a very peculiar image: that the sun emanates rays not like sound or ripples, in circles,[2] but in rays, like a focused searchlight. Hence he is led to the odd (but in its way, scientifically logical) speculation that the sun's rays stretch out only to the fifth sign of the zodiac, because otherwise the planets would be incinerated if they orbited closer to the sun. See Figure 112.

in the same triangle (9.1.11)

Trigon is the normal astrological term but because it simply means *triangle* in Greek; the latter translation is used to relate the present passage to Vitruvius's description of theater design (6.5) and other triangles in 9.praef.5–6 and 9.4.6.

Berosus (9.2.1)

Priest of Bel (fl. c. 290 B.C.) and author of a history of Babylon. This book was one of the main vehicles for the later transmission of Babylonian astronomy to Hellenistic Greece.

Aristarchus of Samos (9.2.3)

Astronomer (first half of third century B.C.), best known as the author of a heliocentric theory of the universe.

the sun . . . diminishes the space
of the days and hours (9.3.1)

One of the major problems in the design of timepieces was that in antiquity the day and the night were divided into twelve equal hours each, but because the day and the night were never equal (except at the equinoxes) the length of the hours of each changed throughout the seasons; daylight hours were long in summer, short in winter, and so on. Any clock had to account for that.

the eighth degree (9.3.1) (Figure 111)

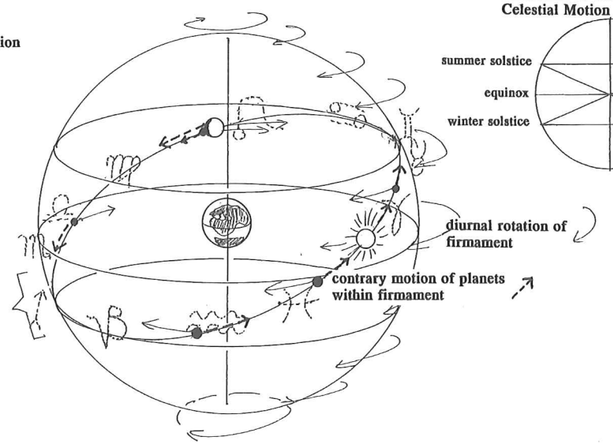
The signs are begun differently in different traditions: Hipparchus, on the entry of the sun into a sign (the first degree); Meton on the eighth degree of the sign. Also note that the precession of the equinoxes (caused by the gradual wobble of the earth's axis, discovered by Hipparchus in the second century B.C.) has displaced the entire zodiacal calendar by about a month. Vitruvius works from the state of the stars c. 200 B.C., as do modern newspaper horoscopes.

1 Pliny the Elder, *Natural History* 2.182; 6.211–220. The next major step was taken by Hipparchus in the next century with his calculation of the tables of chords.

2 Cf. 5.3.6, on the acoustics of theaters: "The voice is a flowing breath of air. . . . It moves by the endless formation of circles."

PLANETARY MOTION (9.1.1-6)

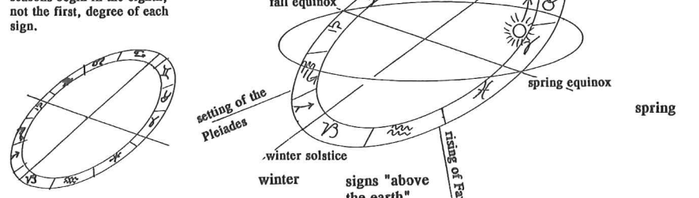
Apparent "Ptolemaic" Celestial Motion



Analemma as Chart of Celestial Motion

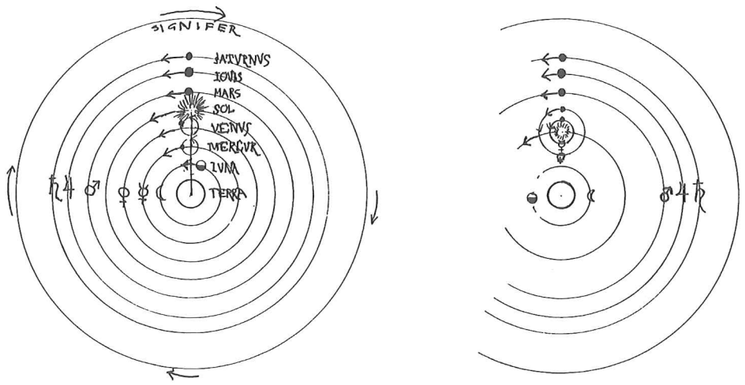
Seasons and Motion of the Sun Through the Belt of Signs (Zodiac)

Note: for Vitruvius, the seasons begin in the eighth, not the first, degree of each sign.



The Belt of Signs in "trigona"

Planetary Orbits (Mercury and Venus orbiting "the rays of the sun")

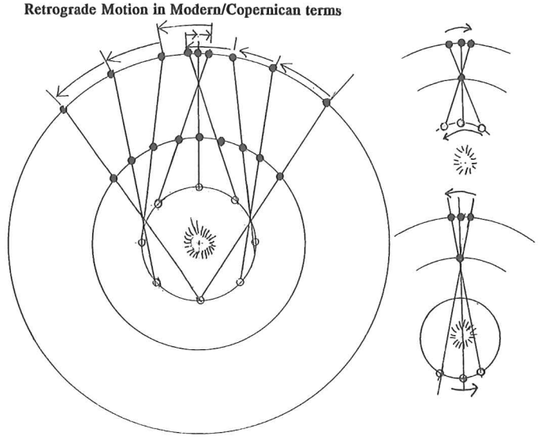


System of Herakleides of Pontus: Mercury and Venus orbiting the sun. (Macrobius, Somn. Scip. 1.19.5)

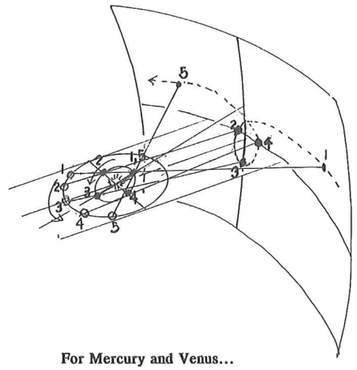
Figure 111. Planetary Motion (9.1.1–6).

RETROGRADE MOTION FOR PLANETS ("STARS") ABOVE THE SUN (9.1.11-15)

Retrograde Motion in Modern/Copernican terms

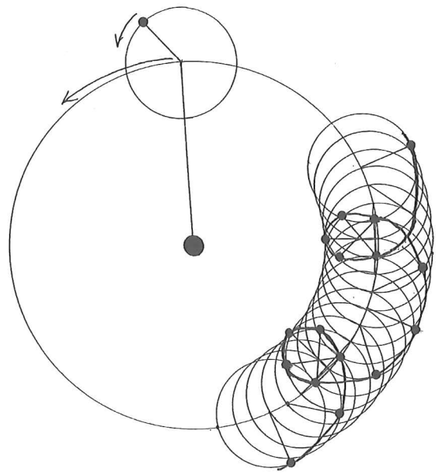


For Mars, Jupiter and Saturn, retrograde motion generally occurs when earth is between sun and planet.

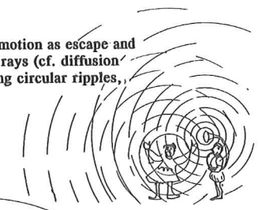


For Mercury and Venus...

Retrograde Motion in Ancient/Ptolemaic terms as the result of epicycles and deferents...



Vitruvius: retrograde motion as escape and capture by the sun's rays (cf. diffusion of sound by expanding circular ripples, 5.1.7).



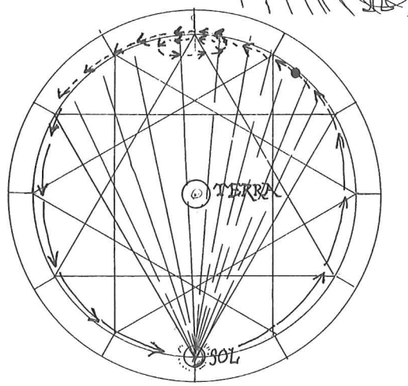


Figure 112. Retrograde Motion for the Planets ("Stars") "Above" the Sun (9.1.11–15).

same course as it had entering Gemini (9.3.2)

This is an attempt to emphasize the symmetry of the seasons.

the ear of Grain (9.4.1)

The star Spica, now Spiga.

colored star in the middle of the knees (9.4.1)

Arcturus. The word *genuorum* is very plebeian Latin.

Pole Star (9.4.6)

There was no real pole star at the time. The Pole was between the tail of the Little Bear and Draco. Vitruvius uses an approximate pole star in Draco, which he distinguishes from the real, unmarked pole.

isosceles triangle (9.4.6)

An isosceles triangle is also equilateral (two sides) in Vitruvius.

right (9.4.6)

Right and left are confused in Vitruvius or the MSS, or both. The ancient travel writer Pausanias has the same problem in distinguishing between the viewer's right and the object's right in his guidebook to Greece.

the star of Canopus (9.5.4)

This implies reports of the firmament as far south as 60° S, which, of course, would be visible from Syene at c. 23 1/2° N.

learned reasoning of the Chaldeans . . . future events by reasoning from the stars (9.6.2)

The border between scientific astronomy and astrology was recognized in antiquity, but it was rather difficult to place. There was a certain revival of traditional augural/astrological practices in the Augustan period, including technical works on astrology by Varro, Nigidius Figulus (praetor 58, died 5 B.C.), and Manilius.

Anaxagoras of Clazomenae,
Pythagoras of Samos, Xenophanes of Colophon,
Democritus of Abdera . . . Eudoxus, Euclemon,
Callippus, Meton, Philippus, Hipparchus, Aratus (9.6.3)

Many of these natural philosophers/astronomers have been mentioned already several times. Xenophanes of Colophon (later sixth century B.C.); Eudoxus of Cnidos (390–337 B.C.), student of Plato, who took up the latter's challenge to devise a rational explanation for the movement of the planets, and the originator of the mathematically sophisticated and influential theory of homocentric rotating invisible ethereal spheres to explain the motions of the planets (including retrograde motions) by means of combinations of "perfect" uniform circular motions; Euclemon (or Euctemon), a collaborator of Meton; Callippus of Cyzicus (c. 370–334), who modified the system of Eudoxus; Meton (fl. 432 B.C.), the orginator of the nineteen-year "Metonic cycle" to synchronize the cycle of the moon with the motions of the sun; Hipparchus of Nicaea (mid-second century B.C.), probably the greatest astronomer of antiquity and the basis of much of the work of Ptolemy; Aratus of Soli (315–240/39 B.C.), author of the very popular *Phaenomena*, a versification of the prose essays of Eudoxus undertaken at the behest of Antigonus Gonatas, king of Macedon, which led to several Latin translations, including one by Cicero.

astronomical tables *[parapegmata]* (9.6.3)

Written tables/calendars of star positions, such as survive in Ptolemy's *Almagest*.

Rome . . . 9:8 (9.7.1) (Figures 114, 115)

Rome is at 41° 54′, 9:8 = 41° 38′. 9:8 is also the value given by Pliny for Rome (*Natural History* 2.182, 6.217).

one-fifteenth part of the entire circle (9.7.4)

This counts as Vitruvius's approximation of the inclination of the ecliptic, 360°/15 = 24°. It was actually about 23° 51′ 19″ at the time of Vitruvius.[3]

the letter A (9.7.4) (Figure 114)

The text for the next few sentences is corrupt; our text follows the logic of the illustration.

the kinds that have been handed down to us (9.7.7)

The most common type of sundial now, in which the gnomon is made more accurate by making it parallel to the earth's axis, seems to have been invented about fifty years after Vitruvius.[4] See sundial of Berosus, 9.8.1: "undercut to follow the earth's tilt."

water jets and automata (9.8.4)

This is a reference to the complex field of entertainment automata used mainly in the theater.[5]

removal of wedges (9.8.6) (Figure 116)

Wedges were a very basic method for controlling, tightening, and leveling all sorts of machines or structures in antiquity, including, presumably, leveling the chorobate.

winter clocks . . ."pickup" (9.8.8) (Figure 117)

For use when it is dark. "Anaphoric" = pickup.

sphere indicates (9.8.9) (Figure 117)

This is the pointer that indicates the current time in the outer grill.

As for regulating the water
supply (9.8.11–12) (Figure 117)

This is a different clock from the above, and it functions by differential water pressure.

3 J. Soubiran, ed., *Vitruve, de l'architecture*, ix (Paris, 1969), 223.
4 R. Newton Mayall, M. W. Mayall, *Sundials* (Boston, 1938), 15.
5 See R. S. Brumbaugh, *Ancient Greek Gadgets and Machines* (New York, 1966).

THE CONSTELLATIONS (9.3-5)

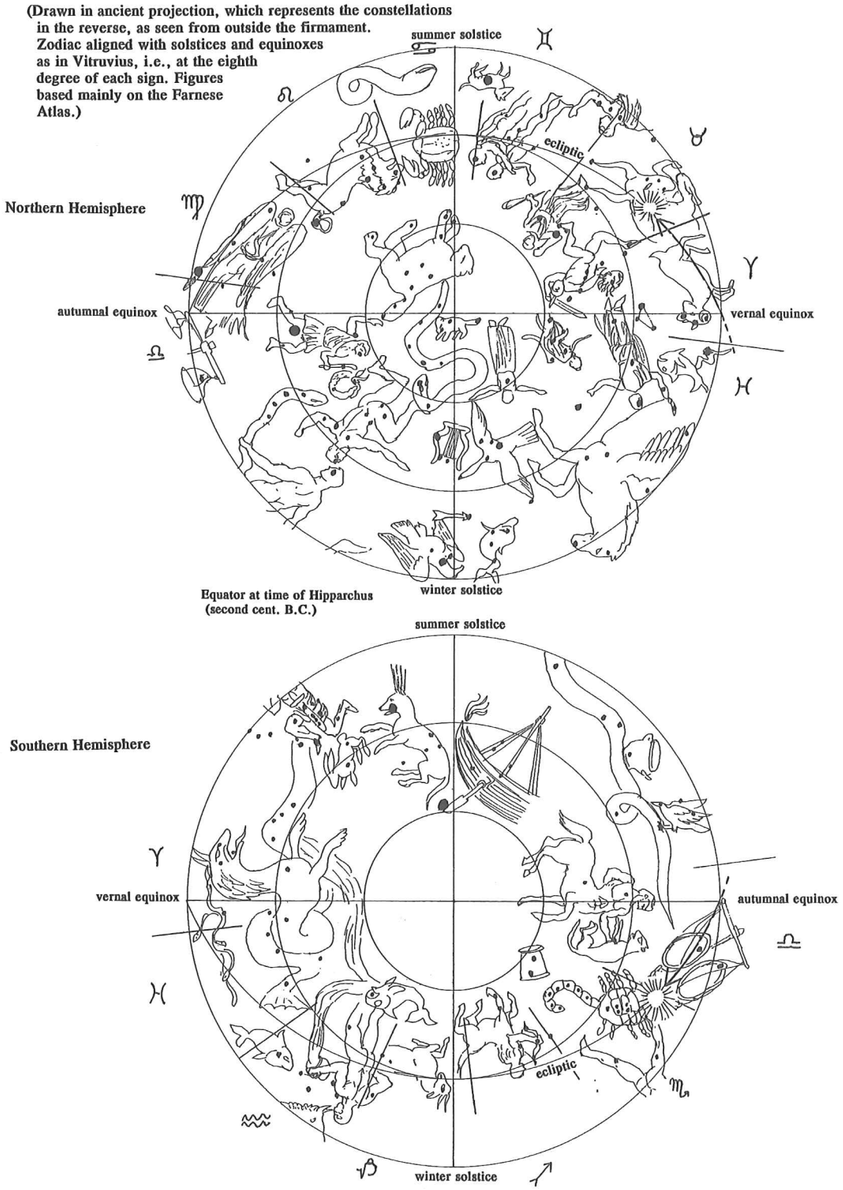


Figure 113. The Constellations (9.3.5).

THE ANALEMMA (9.7.1-7)

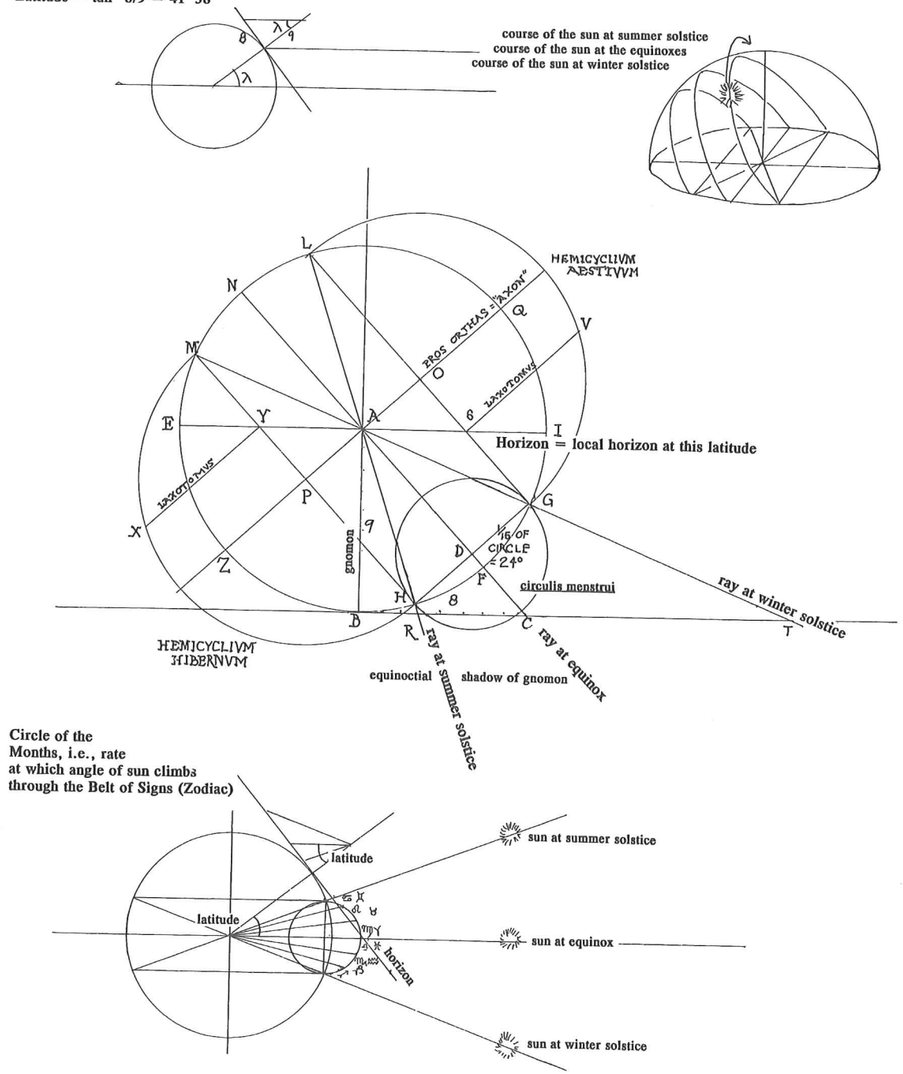
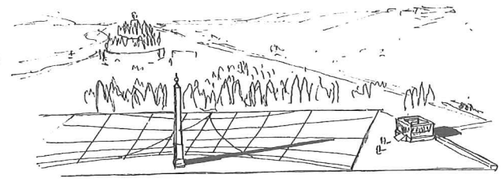


Figure 114. The Analemma (9.7.1–7).

THE ANALEMMA (9.7.1-7)

Partial demonstration of the derivation of a "pelecinum" sundial for the latitude of Rome from the analemma. This drawing shows the projection of the lines of the signs (months) on to the equinoctial line, with the rest of the sundial added. All of the features of the sundial are derived from the analemma.



The Solarium of Augustus and the Ara Pacis
[after E. Büchner, Die Sonnenuhr des Augustus (Mainz, 1982), fig. 13.]

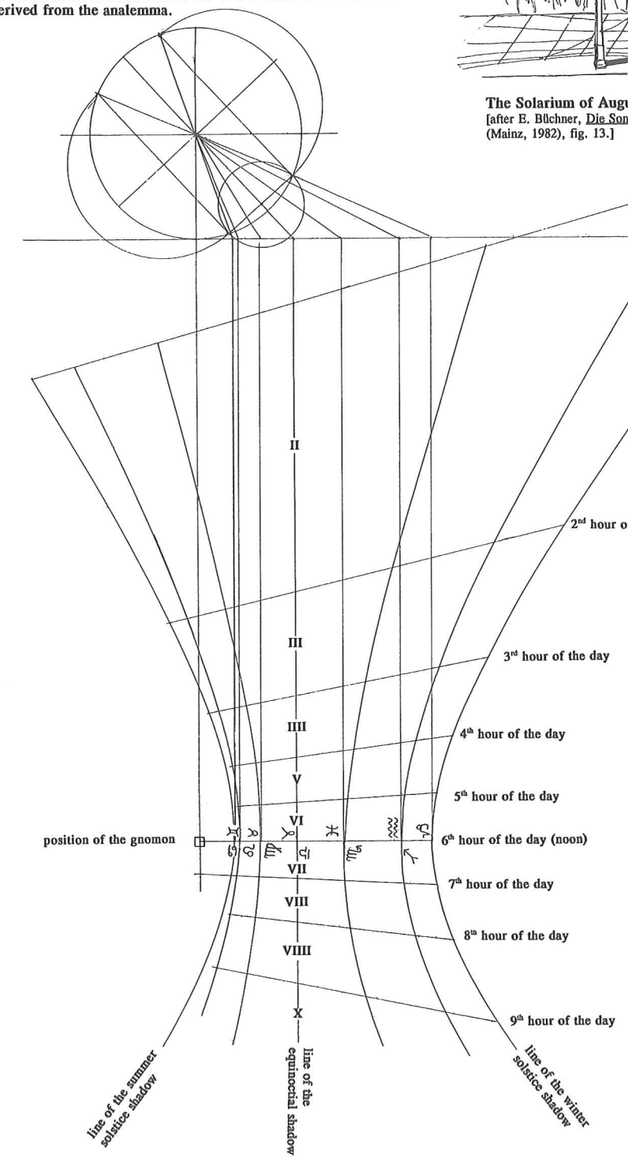
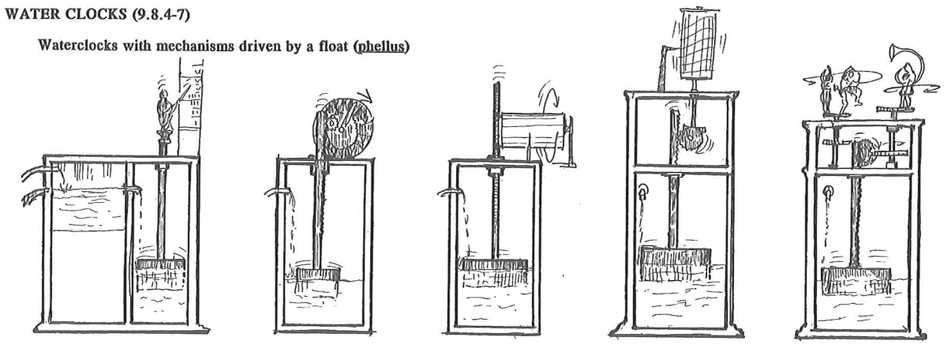


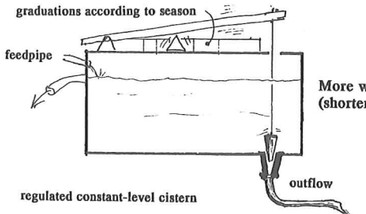
Figure 115. The Analemma (9.7.1–7).

WATER CLOCKS (9.8.4-7)

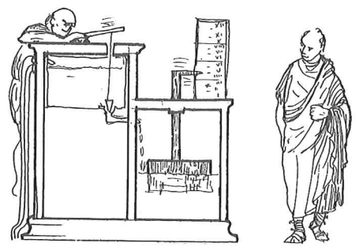
Waterclocks with mechanisms driven by a float (phellus)



Adjusting the flow of water and the length of the hours to the season by use of wedges and conical plugs.



More waterflow in winter (shorter daylight hours)

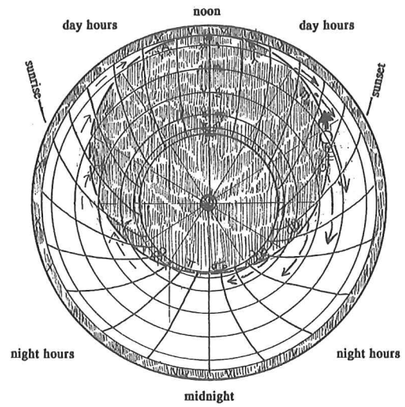


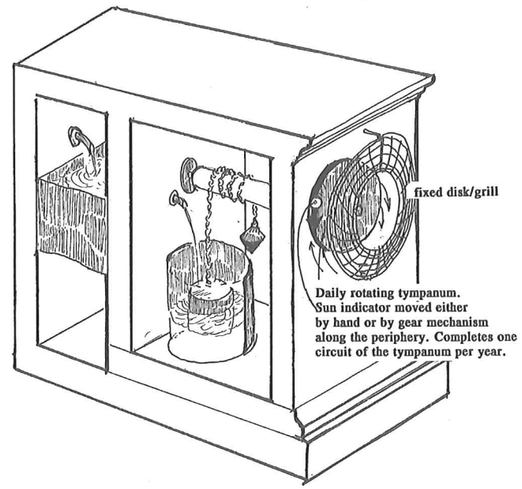
Adjusting the length of the hours to the season by a graduated colonnette, rotated 1/365th each day.

Figure 116. Water Clocks (9.8.4–7).

WATER CLOCKS (9.8.8)

Winter Clocks ("Anaphoric")(9.8.8-10)





Adjustment to Season by Regulation of Waterflow (9.8.11-15)

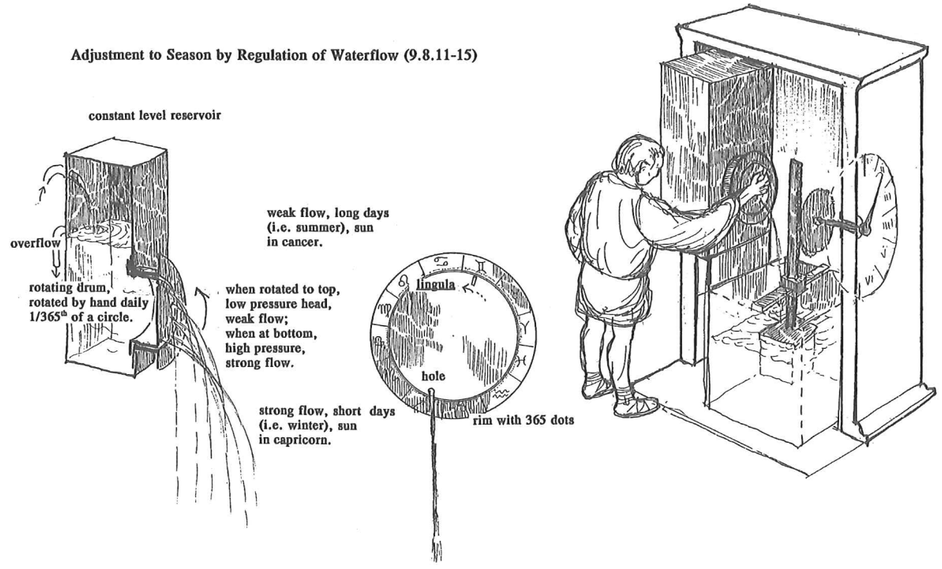


Figure 117. Water Clocks: Winter Clocks (9.8.8).

BOOK 10

people who can assemble
four hundred thousand sesterces (10.praef.2)

Four hundred thousand sesterces were the minimum property qualification for senatorial rank in Vitruvius's day, 100,000 for equestrian rank. The daily wage of a workman would be about one to three denarii. Large sums were usually tallied in 1000s of sestertii, or talents. The property qualification of a senator was 400,000 sestertii in the first century B.C. One of the largest fortunes was that of M. Licinius Crassus, which rose from 300 to 7,000 talents (42 million denarii).[1] L. Licinius Lucullus threw dinner parties costing as much as 50,000 denarii.[2] Top prices for luxurious *domus* (townhouses/mansions) in prime locations in Rome would be a couple of million sestertii; in 62 B.C. Cicero paid 3.5 million sestertii for his house in the Velia (in the upper Forum), and he complained about the high cost and heavy debts caused by this political necessity.[3] The highest known price paid for a house in Rome in the Republic was 14.8 million sestertii.[4]

endowments made by magistrates
for the festival games: the gladiators
the Forum . . . the awnings (10.praef.3)

Temporary, and apparently quite elaborate, wooden theaters were erected every year, usually under the supervision of the aediles, for certain festivals, and gladiatorial combats continued in the Forum until the end of the Republic. The theaters were usually built in the Campus Martius or on the site of the Augustan Theater of Marcellus. In 52 B.C. C. Curio built two rotating wooden theaters, M. Aemilius Scaurus, aedile in 58, built a theater with 360 marble columns for the scaenae frons, and later removed several of them to his house. In 46 Caesar built a "hunting" theater, stadium, and artificial lake for sea fights (naumachiae).[5] M. Claudius Marcellus, aedile in 25, built an awning over the entire Forum for gladiatorial combats.[6] At the time Vitruvius wrote the only stone theater in Rome was that of Pompey (60–55 B.C.); that of Marcellus may have been visible (begun c. 45 or 23, dedicated 17 B.C.); that of L. Cornelius Balbus (19–13 B.C.) was probably not yet begun. The first stone amphitheater in the City (of T. Statilius Taurus) was dedicated in 29 B.C.

1 Plutarch, Crassus, 2.1. seq.
2 Plutarch, Lucullus, 41.7.
3 Cicero, *Epistulae ad familiares* 5.6.2. Velleius, 2.14.2.
4 This was the notoriously luxurious house of M. Aemilius Scaurus, praetor in 67, who had to sell his house quickly when he went into exile in 54 B.C. The atrium featured four 38-foot columns of lucullean marble. It was located in the same area as Cicero's. Pliny the Elder, *Natural History* 36 113–114. F. Coarelli, "La casa dell'aristocrazia romana secondo Vitruvio," in *Munus non Ingratum*, 178–187.
5 Suetonius, *Caesar* 37.
6 Dio Cassius, 53.3.1. See D. Favro, *The Urban Image of Augustan Rome* (Cambridge, 1996), 39–40, 62.

grounding in mechanics (10.praef.3)

Perhaps one further reason that architects were supposed to know mechanics is that, in some circumstances, they (or the contractor) were responsible for furnishing the equipment of a building as well as its construction. This is implied in an example of a contract for building a villa given by Cato the Elder that specifies benches, stools, mortars, and so on, as well as window fittings, doors, cabinetry.[7]

praetors and aediles (10.praef.4)

Normally throughout the Republic aediles administered the festival entertainments, but in 22 Augustus transferred responsibilities to the much more senior officials of the praetors.

circular motion (10.1.1) (Figure 118)

This appears to be an original piece of analysis, but it is based on scientific attempts to see circular motion behind all mechanical action, such as Hero's (unsuccessful) attempt to demonstrate the relation of circular motion and the mechanical advantage of the inclined plane. See figure.

type used for mounting (10.1.1) (Figure 118)

This ambiguous definition probably relates to any kind of scaffolding or ladder; cf. 7.2.2 where "the machines" seems to be scaffolding for plasterers.

baruoison (10.1.1)

Reading *barouison* for MSS *baruison*, to mean "weight-bearing."

mechanically . . . instrumentally (10.1.3) (Figure 118)

This analytical device seems to derive from Greek writers on mechanics, but the sense is changed by Vitruvius to a functional point of view.

scorpion or anisocycles (10.1.3) (Figure 118)

The scorpion is the term for a small arrow-shooting catapult. The interesting implication here is that it is handled by one person. If the reading "anisocycles" means "unequal circles," then this may refer to *baruoulkon*, a reduction gear lifting device, described by Hero.[8] See figure.

This type of machine (10.2.3)

Ratio is a term of classification for machines, presumably translating the infinitely flexible Greek word *logos*. We see this peculiar Hellenizing use of *ratio* throughout Book 10. There are three *genera* (mounting, pneumatic, and tractor), and then each example within the *genus* seems to be a *ratio*. Within each *ratio* there can be further *genera*.

supporting ropes . . . shoulders (10.2.3) (Figure 120)

Supporting ropes = stays. Shoulders (*scapulae*) are presumably some upper part of the crane, perhaps where the two beams join.

7 *De Agri cultura*, 14.1–5.
8 *Mechanica* 1.1; 2.21; *Dioptra* 37, postdating Vitruvius (c. A.D. 65).

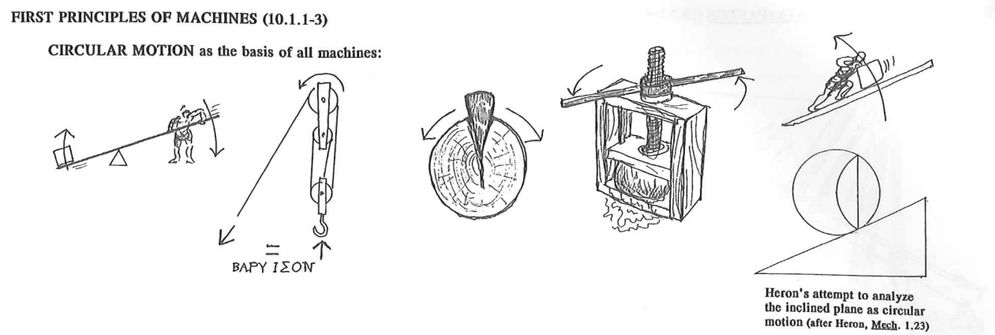


Figure 118. First Principles of Machines (10.1.1–3).

CRANES: TRISPASTOS/PENTASPASTOS (10.2.1-4)

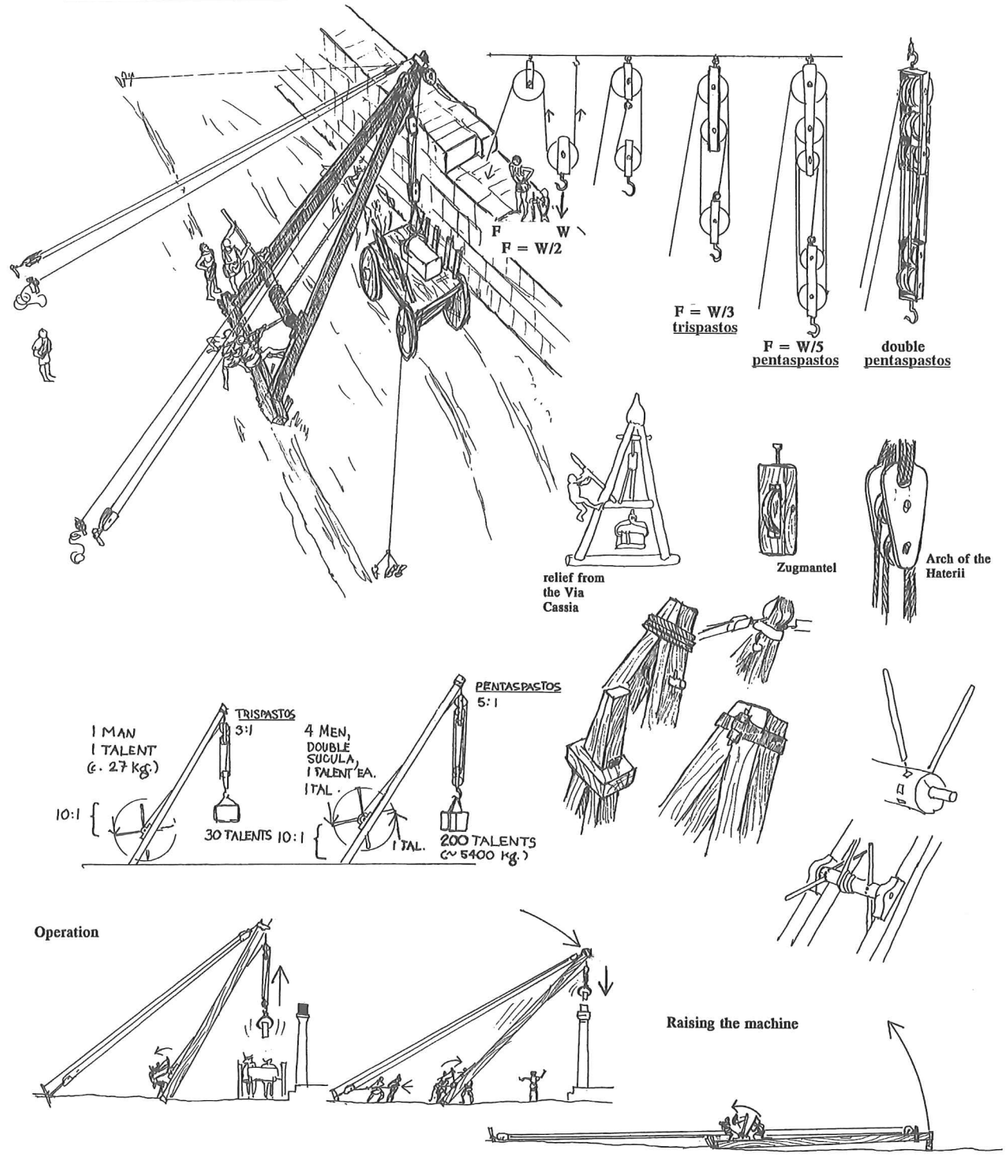
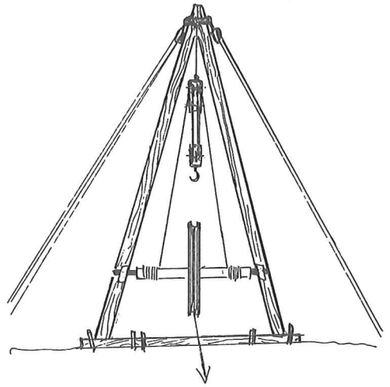
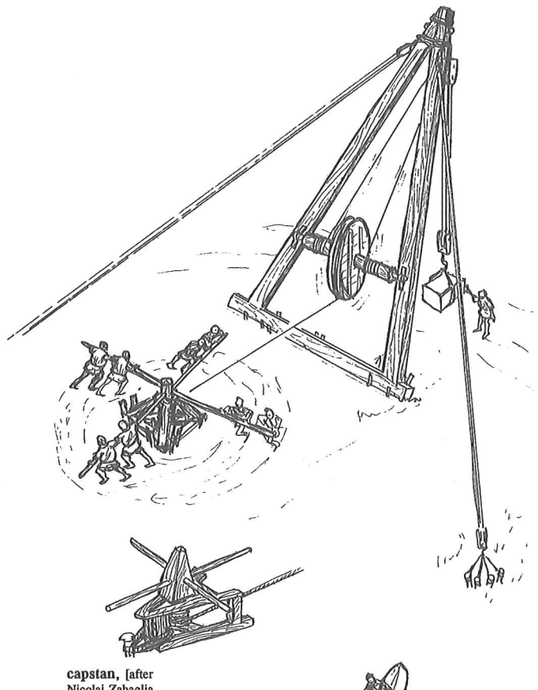


Figure 119. Cranes: *Trispastos/Pentaspastos* (10.2.1–4).

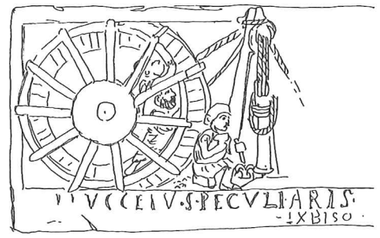
CRANES FOR HEAVIER LOADS (10.2.5-7)

WITH REDUCTION GEAR (amphiesis, perithêkion)



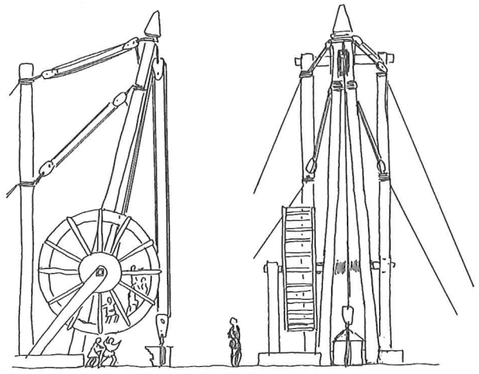


TREADMILL-DRUM PLACED TO THE SIDE



relief from Capua

capstan, [after Nicolai Zabaglia, Contignationes ad pontes, (Romae, 1743).]



reconstruction based on the Arch of the Haterii

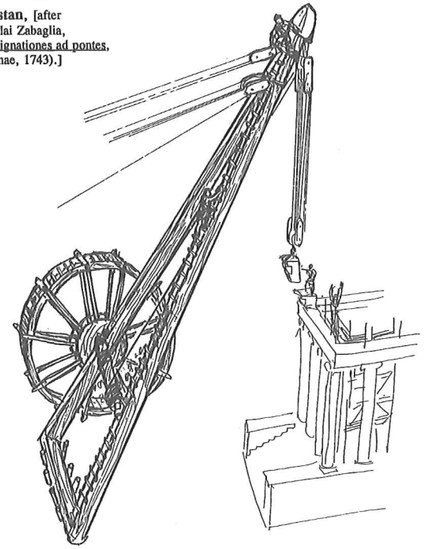


Figure 120. Cranes for Heavier Loads (10.2.5–7).

maneuvered by control ropes (10.2.8) (Figure 121)

Maneuvered (*distendo*) = "made to reach." This type of motion is indeed very difficult to coordinate between four rigging gangs.

the colossal statue of Apollo (10.2.13)

From the context this must be an Apollo at Ephesus, but the exact identification is debatable; possibly it is to be identified with a work of Myron, stolen by Marc Antony and returned by Augustus.[9]

Paconius (10.2.13) (Figure 122)

Unknown by any other source, Paconius may be a Roman working in Asia Minor, or if read as Paeonius, he may be identified with Paeonius of Ephesus mentioned in 7.praef.16. The latter, however, is a fourth-century B.C. architect, and this Paconius is a contemporary of Vitruvius.

Paros, Proconnesus, Heraclea, Thasos (10.2.15)

Parian is the basic statuary marble of Greek antiquity; Proconnesian, a blue-white marble from quarries on the isle of Proconnesus in the Sea of Marmara; and Thasian a bright white coarse-grained marble from Thasos in the northern Aegean. The latter two were exported in large quantities throughout the Empire. Heraclea may be Heraclea ad Latmos.

linear motion . . . circular motion (10.3.1–8)

This analytical section is partly original, and partly derives from the tradition continued (later) by Heron of Alexandria in trying to see circular motion underlying all levers, inclined planes, and so on.[10] The notion that sailboats go faster when their sails are raised higher up the mast because the sail has a longer lever arm is, of course, wrong; speed is proportional to sail area, torque (heeling) is proportional to height of mast (and weight of ballast). See figure.

the pilot of the largest cargo ship (10.3.5) (Figure 123)

Lucian gives a vivid picture of a precarious passage from Alexandria to Rome on a 180-foot ship in which "all depended for its safety on one little old man who turns those great steering oars with a tiller that's no more than a stick!"[11]

double iron chain (10.4.4) (Figure 125)

Presumably attached at each side of each bucket. *Congius* = 6 *sextarii* = c. 3.275 liters.

Water mills (10.5.2) (Figure 126)

Water mills were apparently a fairly recent invention, probably appearing only in the late first century B.C. Vitruvius does not mention the overshot wheel or the horizontal wheel, but both were certainly used by later antiquity. Vitruvius's mill is geared down, that is, with the grindstone rotating more slowly than the waterwheel; later, larger European overshot wheels were geared up.[12]

water screw (10.6.1) (Figure 127)

Literally, "water snail."

Ctesibius . . . many others (10.7.4) (Figure 128)

This is another reference to the ingenious automata used mainly as scientific playthings and theater entertainments. There were even plays, like the *Nauplius*, which were performed solely by automata.[13]

water organs (10.8.1–6) (Figure 129)

Water organs were very loud instruments, and they commonly appeared as part of the entertainment for large crowds, such as in circuses.[14] The bronze dolphins are presumably counterweights for the air intake valves. See figure.

a device that is not idle (10.9.1) (Figure 130)

Vitruvius's wording implies strongly that this odd gadget was an actual part of the repertoire of land surveyors. A similar device is also described by Heron, *Dioptra* 34.

four feet . . . twelve and one-half feet (10.9.1)

Vitruvius gives no actual value for pi. MSS read 4 1/6 feet for the diameter of the wheel, 12 1/2 for its presumed circumference, giving a value of pi of 3.00. Reading MSS as 4 feet gives a value of 3.125. Archimedes demonstrates a range of approximations from 3 1/8 (= 3.125) to 3 1/7 (= 3.1429).[15] The number 22/7 is a fairly common approximation in antiquity.

scorpions and ballistae (10.10.1) (Figures 118, 131, 132)

Vitruvius seems to use *scorpio* to distinguish an arrow- or bolt-launching catapult from a *ballist(r)a* or stone-launching catapult, but in 10.1.3 *scorpio* also seems to imply a smaller, one-man weapon. The catapult was invented c. 399 B.C. in Syracuse as a bow-shooter[16] and in the course of the fourth century B.C. developed into the sophisticated twin-arm, twin-spring

9 Pliny the Elder, *Natural History* 34.58.
10 Heron, *Mechanica* 1.9, 2.7, 2.9.
11 Lucian, *Navigium* 5; cited in L. Casson, *Travel in the Ancient World* (Toronto, 1974),158–159.
12 One of the first references is from an epigram from the *Palatine Anthology* (9.418), which celebrates the release from drudgery brought to women servants who previously had to grind by hand. The verse presumably dates from the late first century B.C. Also Lucretius, *De rerum natura* 5.509–33. An overshot wheel is represented in a mosaic from the Palace of the Emperors in Constantinople; *Antiquity* 13 (1939), 354–356, pl. vii. See J. G. Landels, *Engineering in the Ancient World* (Berkeley, 1978), 16–26.
13 The principal source for such information are Heron's *Pneumatica* and *Automata*. See R. S. Brumbaugh, *Ancient Greek Gadgets and Machines* (New York, 1966), 113–129.
14 Pliny the Elder, *Natural History* 7.125; Suetonius, *Nero* 41.4; Tertullian *Animadversiones* 14.
15 J. Pottage, "The Vitruvian Value of pi," *Isis* 59 (1968), 190–197.
16 A large group of expert craftsmen was lured to Syracuse by Dionysius I with the hope of developing weaponry that would give him the advantage over Carthaginian forces. Diodorus Siculus 14.41.4, 42.1. E. W. Marsden, *Greek and Roman Artillery: Historical Development* (Oxford, 1969), 48–49.

machine described in Vitruvius. In more general terms, the Latin *catapulta* meant the arrow- or bolt-shooter, *ballista* the stone-shooter, and a *scorpio* was a smaller *catapulta*. Between c. A.D. 100 and 300 the nomenclature changed, and *catapulta* became the one-armed stone-throwing machine (onager), and *ballista* became the bolt-shooter.[17]

Hellenistic town fortifications were heavily influenced by the development of sophisticated siegecraft and artillery in the fourth century B.C. Because of artillery, crenellations were abandoned on the curtain and replaced with a continuous screen with firing apertures. Towers appeared in order to hold artillery, and to raise it higher, to provide greater range over besieging artillery, and to offer flanking fire to clear the walls; they were roofed and most fighting moved inside, with large ports in the upper stories for artillery (catapults) and smaller loopholes in the lower stories for archers. Small artillery was sometimes placed on the curtain as well. Greek walls continued to be of drystone masonry, but became higher and thicker, commonly developing into header and stretcher or "compartment" walls with mud and rubble infill, to resist stone-throwing catapults. Stone-throwing catapults (*petroboloi*) could often shatter crenellations or cave in chambers of towers, but never an earth-backed wall. From the later fourth century, fortifications developed ditches and outworks (*proteichismata*) whose purpose was to keep siege machinery at a distance from the walls[18] (Figures 15–19).

proposed length of the arrow (10.10.2)

Usually measured in "spans," 1 span = 3 palms.

five-digit (10.11.3)

The principal texts on catapults are Ctesibius of Alexandria (mid-third century), Biton (third century), Philo of Byzantium (c. 200 B.C.), Vitruvius, and Hero of Alexandria (first century A.D.). Vitruvius follows Philo on the dimensions of the *ballista* in all but a few details.[19] Marsden emends Vitruvius's dimensions in digits to unciae, on the grounds that otherwise his machines have springs three-quarters the diameter of Philo's.[20]

their tension is tempered by ropes (10.11.9; 10.12.1–2) (Figure 133)

A similar device is also described in Hero's *Belopoeica*, 107–113.[21] The material of springs was either sinew or nerve, presumably woven to a rope, although women's hair also could be used.[22]

First of all, the ram . . .
is said to have been invented . . . (10.13.1)

Chapters 13, 14, and 15 of Book 10 are almost identical to chapters on siegecraft from Athenaeus Mechanicus's *Peri Mechanêmatôn*,[23] so much that either could be a translation of the other. The common source is probably the late second-century B.C. engineer Agesistratus, whom Vitruvius credits in 7.praef.14; Athenaeus was likely a contemporary of Vitruvius.[24]

Gades (10.13.1)

Cadiz, possibly c. 500 B.C. Most siegecraft up to c. 400 B.C. was developed by Carthaginians; to conquer Selinus in 409, Carthaginian attackers used six siege towers, six rams, archers, and slingers. At Himera, (407) they used mines and pit props, at Akragas (406), siege mounds.[25]

Philip . . . siege to Byzantium (10.13.3)

The first sieges at which Philip II made extensive use of artillery were Perinthos and Byzantium, both in 340 B.C., and afterward technical leadership in siegecraft passed to the Macedonians. The torsion catapult (as opposed to the bow-shooter) was probably a Macedonian development.[26]

Hegetor of Byzantium (10.15.2) (Figure 137)

Possibly a siege engineer of Demetrius Poliorcetes.

Diognetus . . . Callias . . . Demetrius (10.16.3–4) (Figure 138)

These events are part of the siege of Rhodes in 304 by Demetrius, son of Antigonus of Macedon. It was one of the most spectacular and famous sieges in antiquity and caught the attention of the world on account of the sophistication of the siege machinery.

on Chios . . . *sambucae* (10.16.9) (Figure 138)

It is not known which siege this refers to, but presumably some event in the third or second century B.C. The *sambuca* is a type of ship-borne scaling ladder suspended from a mast, and it is given this name because it resembles the type of stringed harp of the same name.

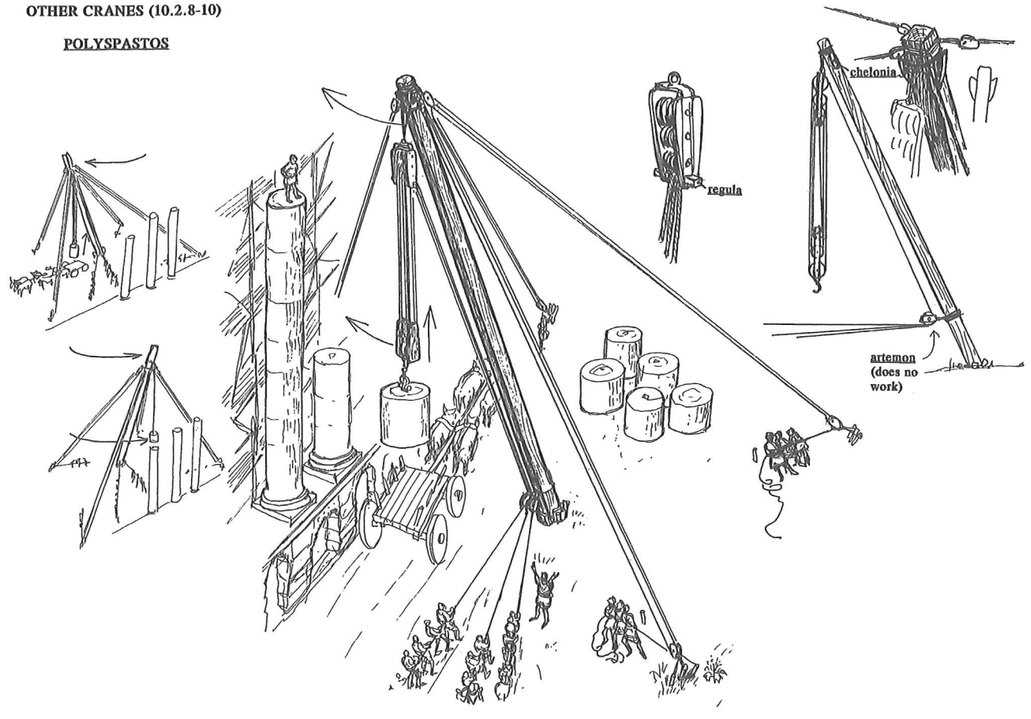
in Apollonia (10.16.9–10) (Figure 138)

Again uncertain, but possibly the siege of Apollonia in Illyria by Philip V of Macedon in 214. Octavian was in Apollonia in 44 when he learned of Julius Caesar's death.

17 Ibid., 1.
18 F. E. Winter, op. cit., 311–333. Other general studies of importance: J. P. Adam, *L'Architecture militaire grecque* (Paris, 1982); F. Krischen, *Die Stadtmauer von Pompeii und die griechische Festungsbaukunst in Unteritalien und Sizilien* (Die Hellenistische Kunst in Pompeii 7) (Berlin, 1941).
19 E. W. Marsden, *Greek and Roman Artillery: Technical Treatises* (Oxford, 1971), 1–14.
20 Ibid., 198–199.
21 Ibid., 37–41.
22 Heron, *Belopoeica* 110–113.
23 ed. Wescher, 9–26.
24 See Marsden, *Greek and Roman Artillery: Technical Treatises*, 4–5, with earlier references.
25 Diodorus Siculus 13.54.7, 13.59.8, 13.86.1–3.
26 Marsden, *Greek and Roman Artillery: Technical Treatises*, 58.

OTHER CRANES (10.2.8-10)

POLYSPASTOS



CRANES FOR SHIPS AND HARBORS

Upright

Flat revolving booms

Ships can be hauled into shore...

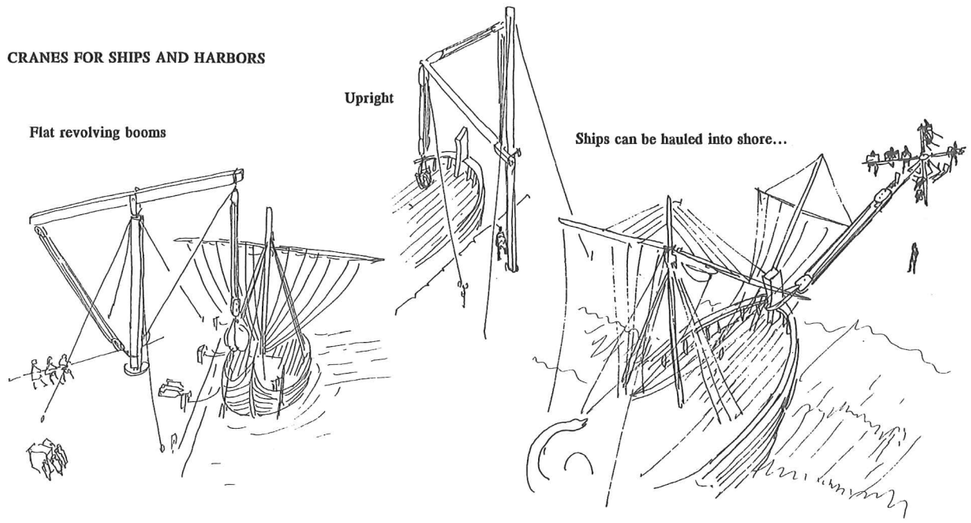
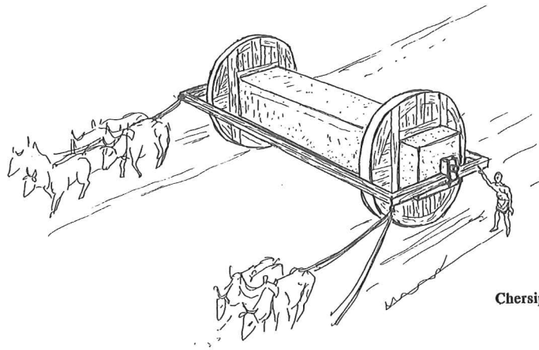


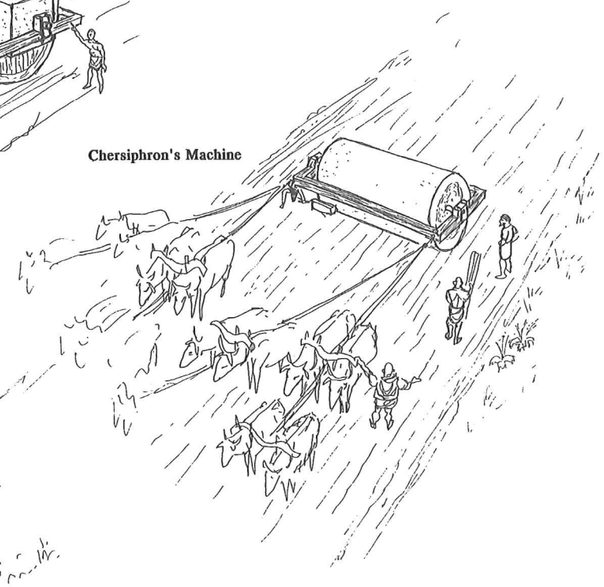
Figure 121. Other Cranes (10.2.8–10).

SPECIAL METHODS OF HAULING LARGE BLOCKS (10.2.11-15)

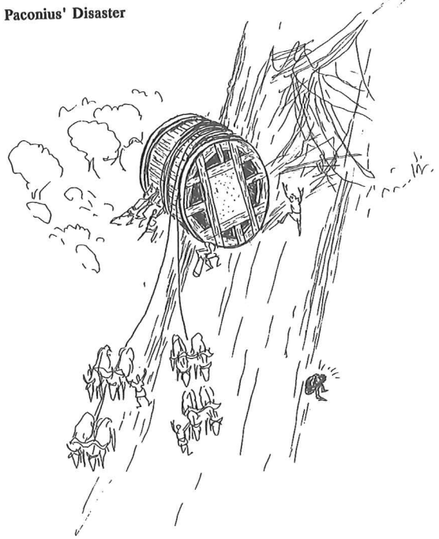
Metagenes' Machine



Chersiphron's Machine



Paconius' Disaster



Cylindri for levelling ambulationes of palaestrae

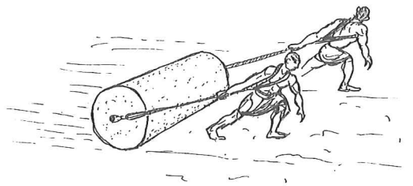
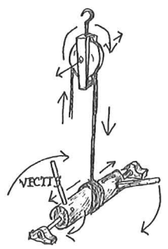


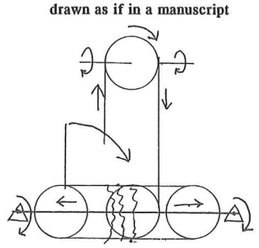
Figure 122. Special Methods of Hauling Large Blocks (10.2.11–15).

ALL MACHINES USE TWO TYPES OF MOTION (10.3.1-8)

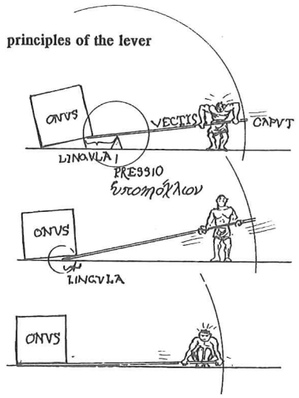
Winch and pulley as combination of straight and circular motion.



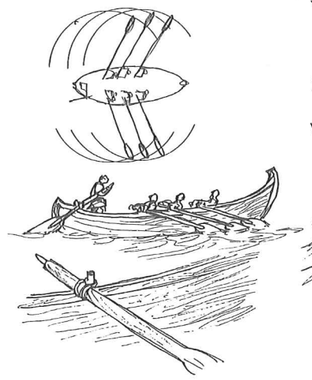
drawn as if in a manuscript



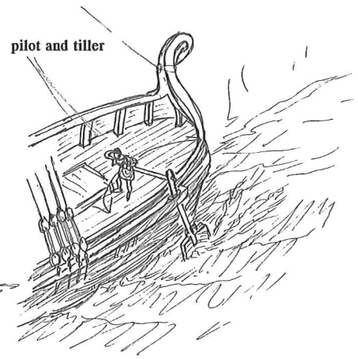
principles of the lever



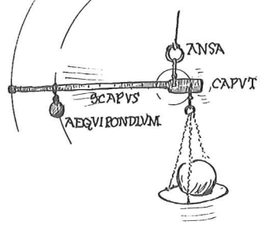
oars



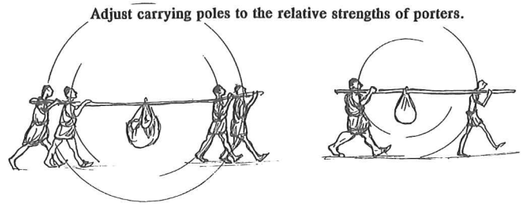
pilot and tiller



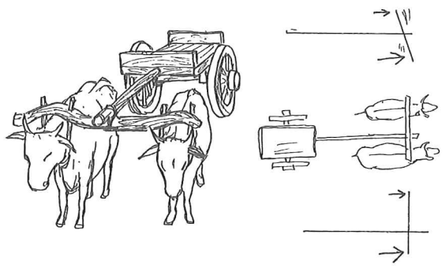
balances (staterae)



Adjust carrying poles to the relative strengths of porters.



Adjust the arms of the yoke for unequal draught animals.



Ships sail faster when yards are drawn to the summit of the mast because of longer lever arm.

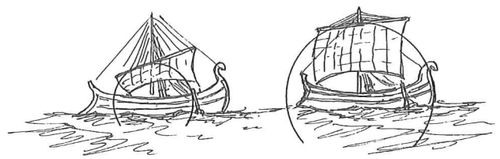
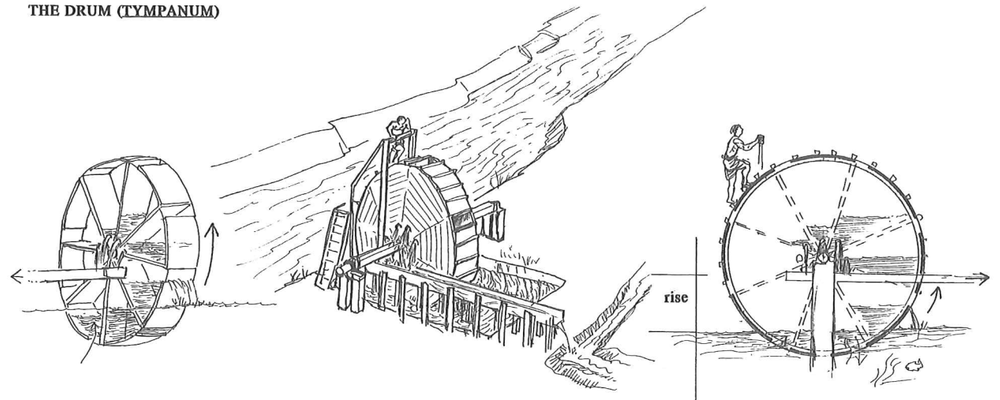


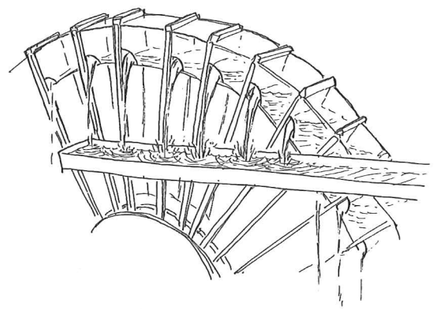
Figure 123. All Machines Use Two Types of Motion (10.3.1–8).

WATER RAISING MACHINES (10.4.1-4)

THE DRUM (TYMPANUM)

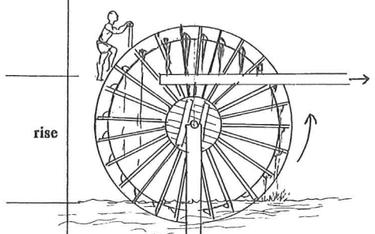


WHEEL WITH "SQUARE BUCKETS" (modioli quadrati)

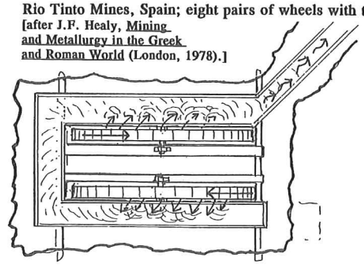


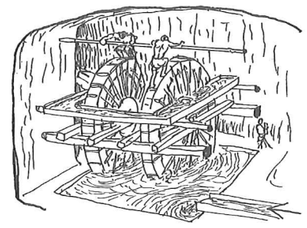
modius

modiolus quadratus?



Rio Tinto Mines, Spain; eight pairs of wheels with total rise of 97 ft.
[after J.F. Healy, Mining and Metallurgy in the Greek and Roman World (London, 1978).]

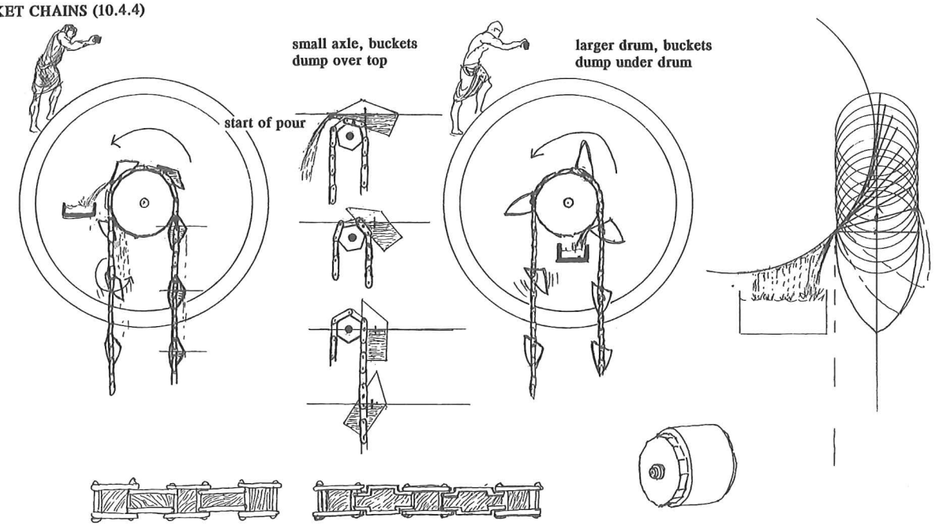




bucket wheel in Louisiana rice paddies, 19/20C.

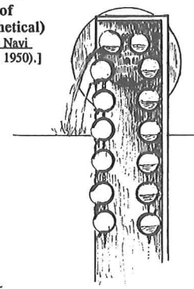
Figure 124. Water Raising Machines (1.4.1–4).

BUCKET CHAINS (10.4.4)



Wood and link chain
[after E.W. Marsden, Greek and Roman Artillery Manuals: Technical Treatises (Oxford, 1970), 182, fig. 20, from a discussion of the repeater catapult in Philon's Belopoeica.)

Bilge pump from the Lago di Nemi wreck (form of bucket hypothetical)
[after Ucelli, Le Navi di Nemi (Rome, 1950).]



Pompeii, Stabian Baths, bucket chain for raising water from well to roof reservoir [after H. Eschebach, Die Stabianerthermen in Pompeji (Berlin, 1979).]

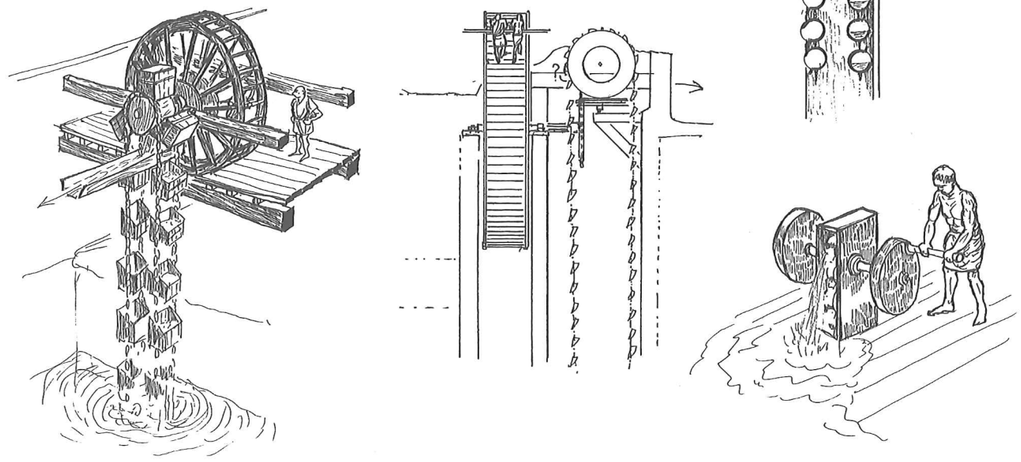
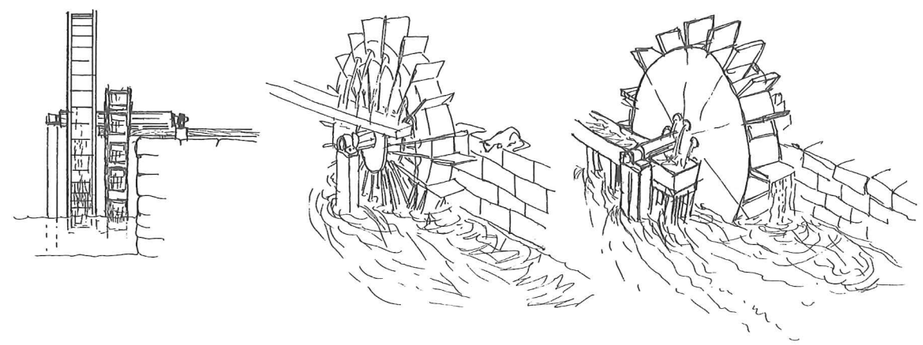


Figure 125. Bucket Chains (10.4.4).

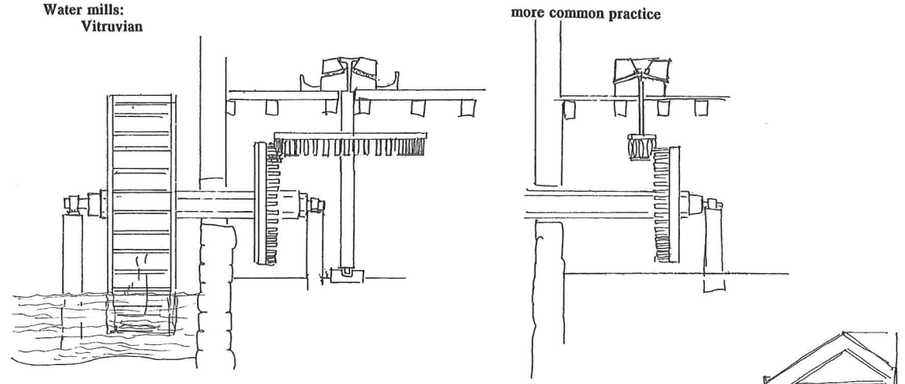
WATERWHEELS (10.5.1-2)

"...wheels are made in rivers by the same principles as those above..."



Water mills:
Vitruvian

more common practice



Mosaic representation of a waterwheel, from Byzantium
[after H. Hodges, Technology in the Ancient World (London, 1970), fig. 226.]

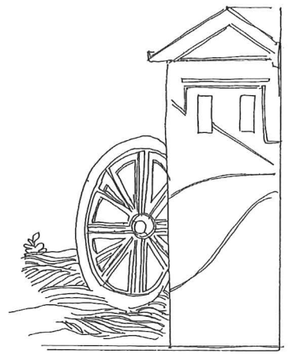
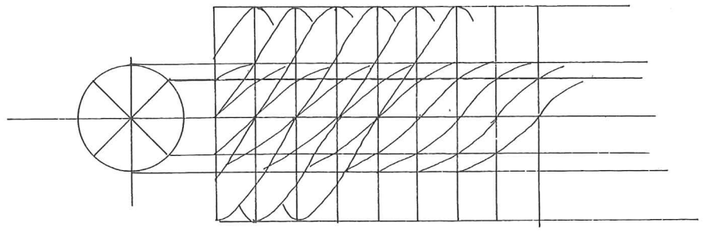
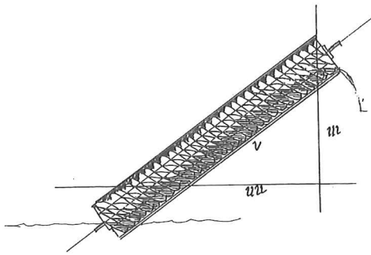
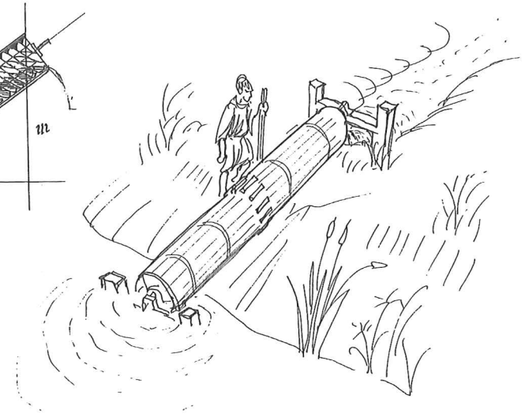


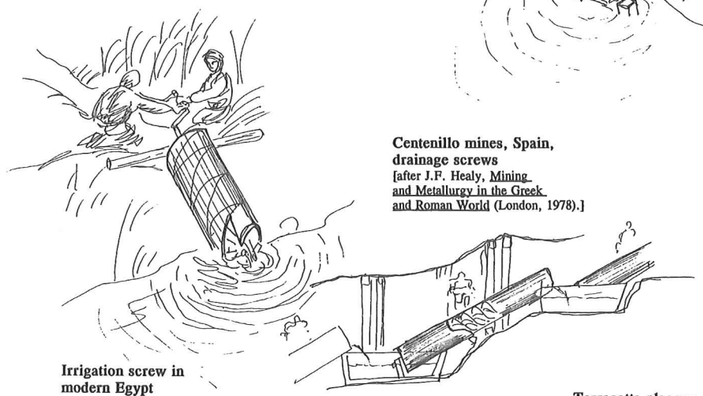
Figure 126. Waterwheels (10.5.1–2).

THE WATER SCREW ("Water Snail," Coclea)(10.6.1-4)









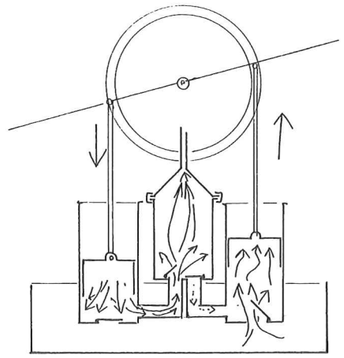
Irrigation screw in modern Egypt
[after H. Hodges, Technology in the Ancient World (London, 1970), fig. 212.]

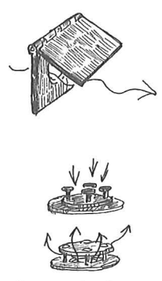
Centenillo mines, Spain, drainage screws
[after J.F. Healy, Mining and Metallurgy in the Greek and Roman World (London, 1978).]

Terracotta placque of a slave on a water screw
[after H. Hodges, Technology in the Ancient World (London, 1970), fig. 226.]

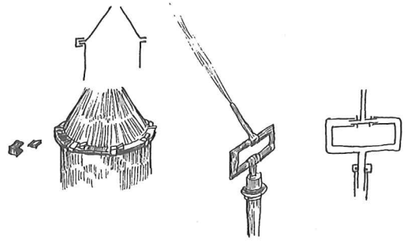
Figure 127. The Water Screw ("Water Snail," *Coclea*) (10.6.1–4).

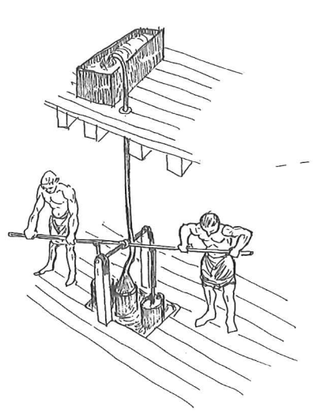
CTESIBIUS'S WATER PUMP (10.7.1-3)



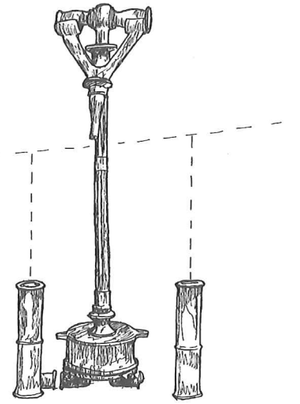


"penny valves" (asses), reconstructions

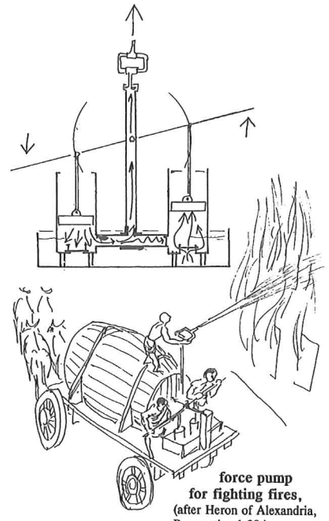




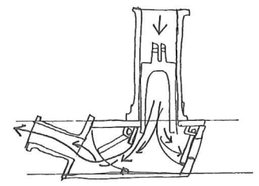
force pump from Bolsena
[from British Museum, in Guide to the Exhibition Illustrating Greek and Roman Life (London, 1920⁵), figs.127, 128.]



force pump from Sotiel, Coronado Mines, Valverde, Spain
[after J.G. Landels, Engineering in the Ancient World (Berkeley and Los Angeles, 1978), fig.24.]



force pump for fighting fires,
(after Heron of Alexandria, Pneumatica 1.20.)



force pump from a merchant ship wreck
[after Landels, [after J.G. Landels, Engineering in the Ancient World (Berkeley and Los Angeles, 1978), fig.25.]

Figure 128. Ctesibius's Water Pump (10.7.1–3).

WATER ORGANS (10.8.1-6)

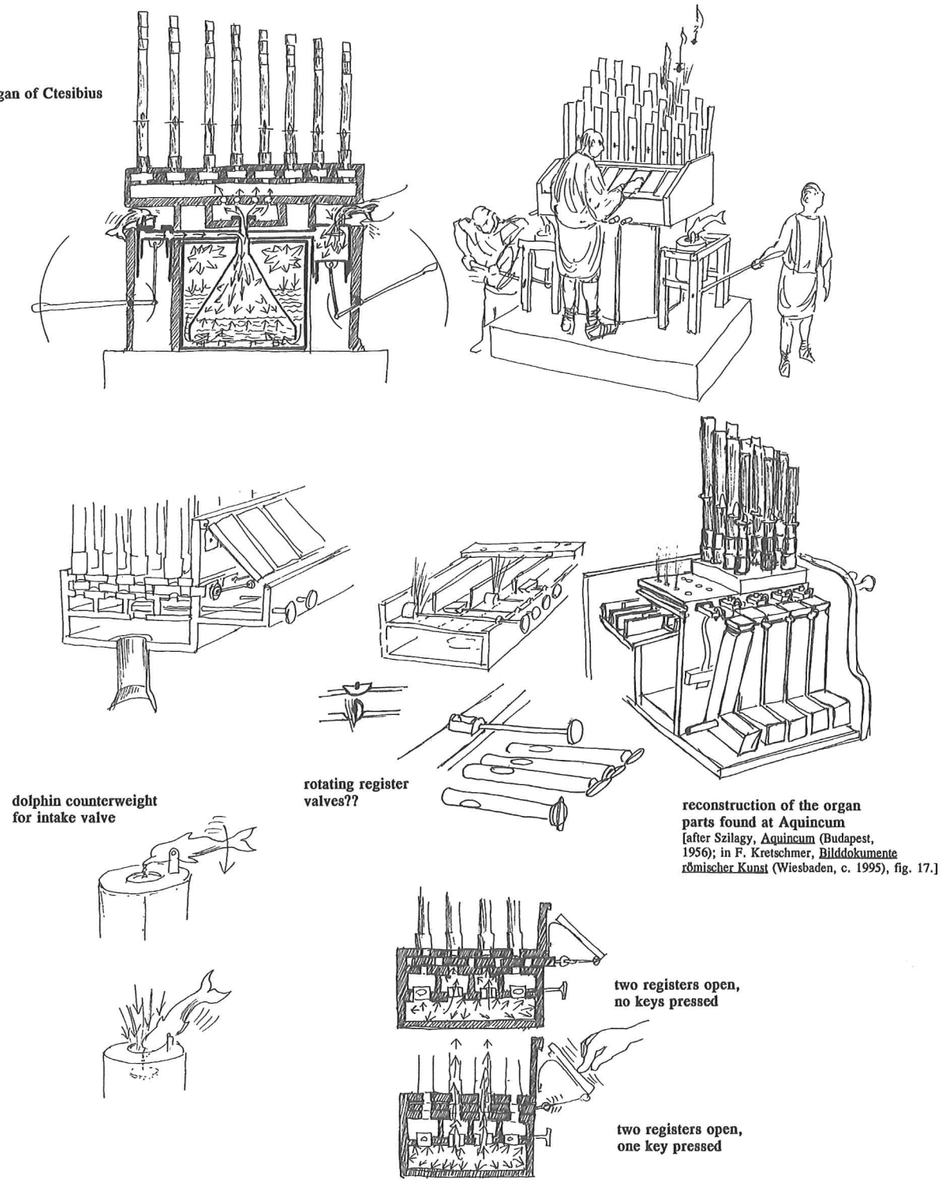


Figure 129. Water Organs (10.8.1–6).

THE HODOMETER (10.9.1-7)

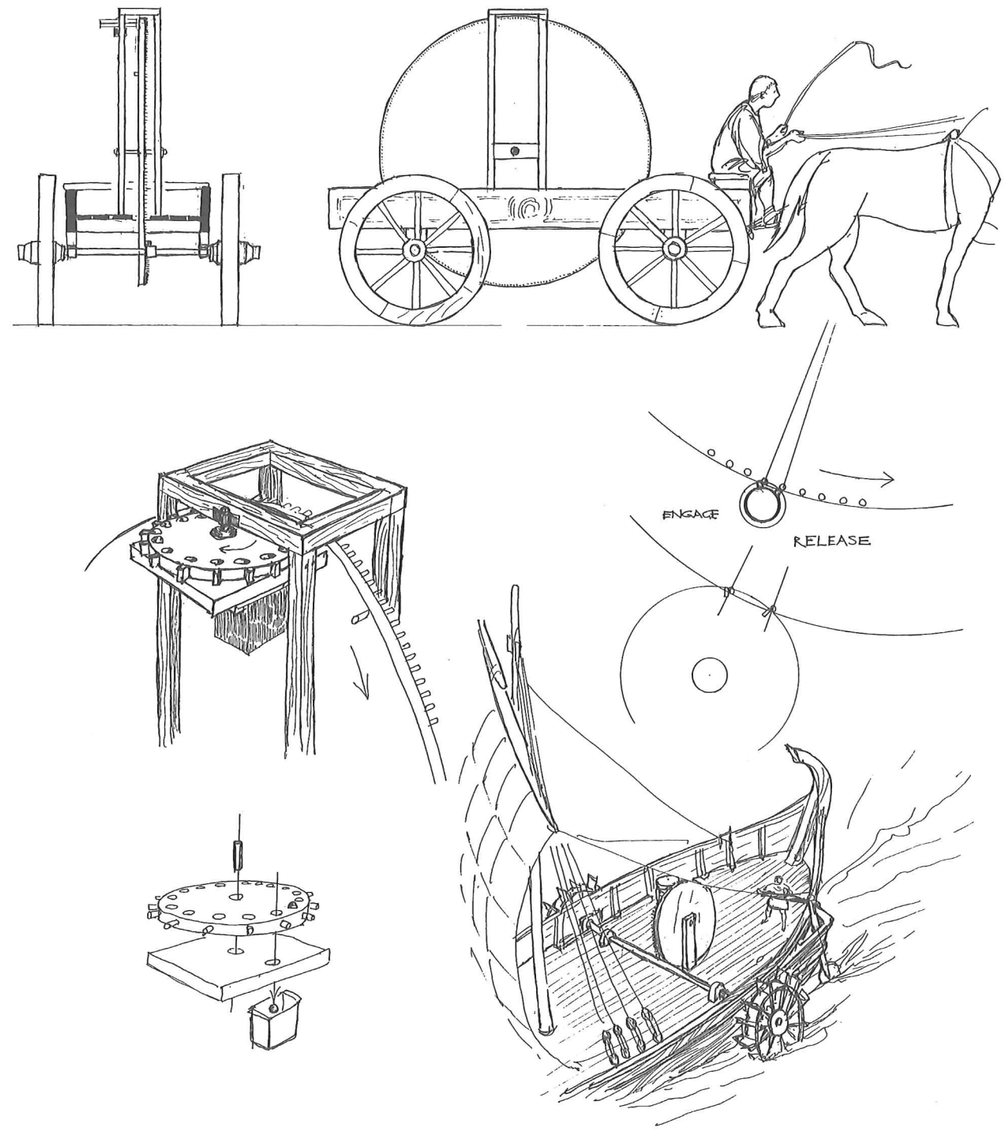
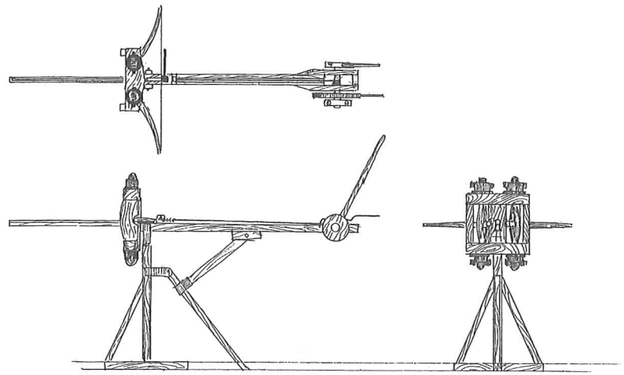


Figure 130. The Hodometer (10.9.1–7).

ARTILLERY: THE SCORPIO (10.10.1-6)



reconstruction [based in part on E.W. Marsden, Greek and Roman Artillery: Historical Development (Oxford, 1969), fig. 1.21; cf. below.]

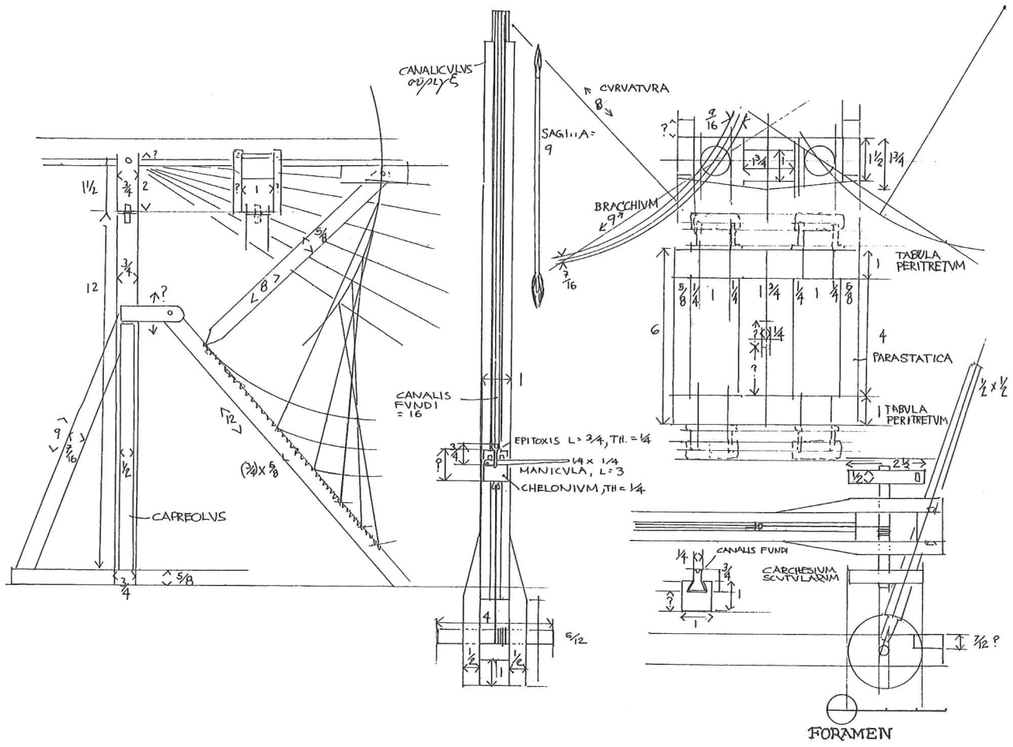
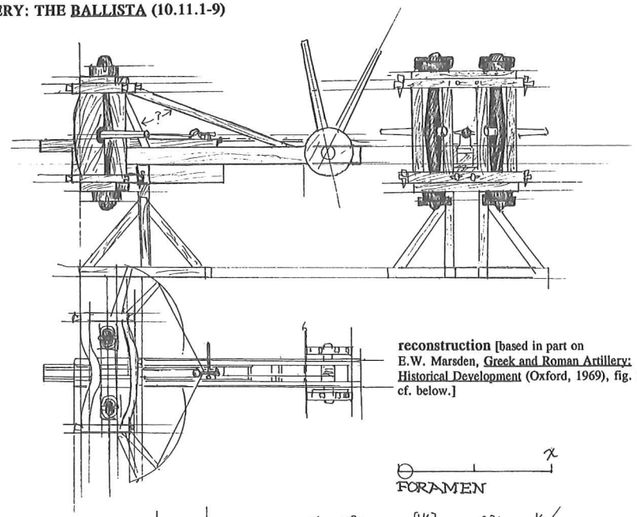
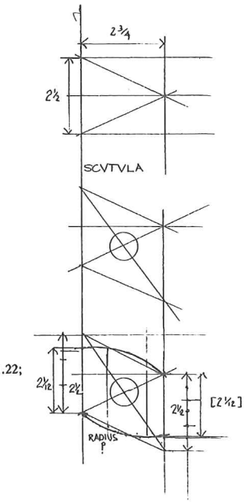


Figure 131. Artillery: The *Scorpio* (10.10.1–6).

ARTILLERY: THE BALLISTA (10.11.1-9)



reconstruction [based in part on E.W. Marsden, Greek and Roman Artillery: Historical Development (Oxford, 1969), fig. 1.22; cf. below.]



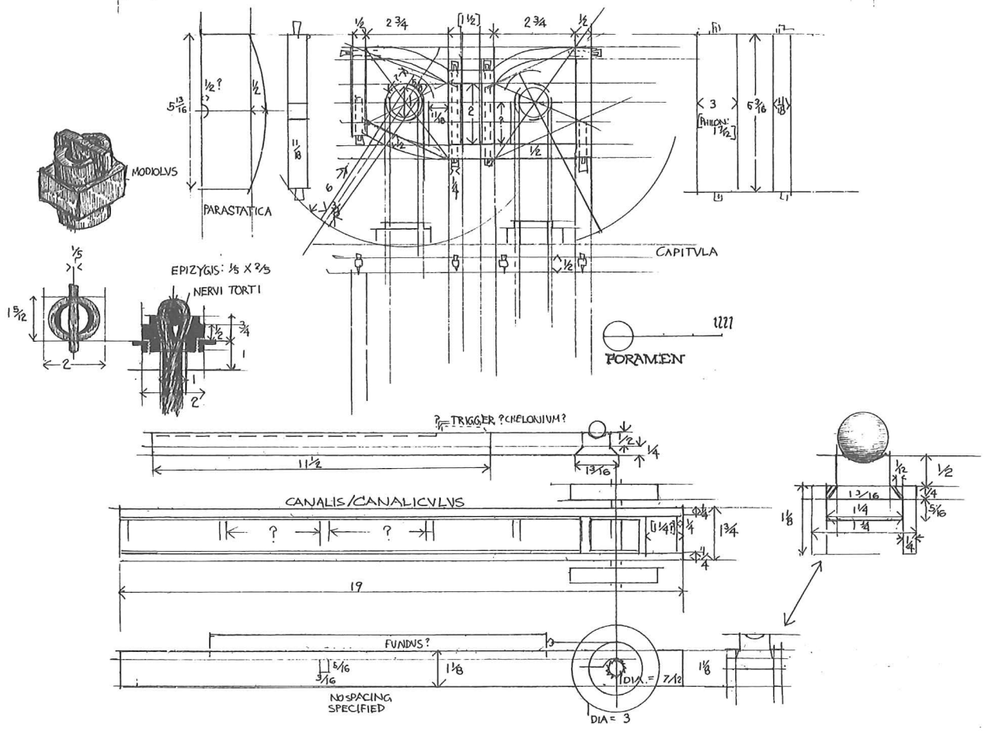
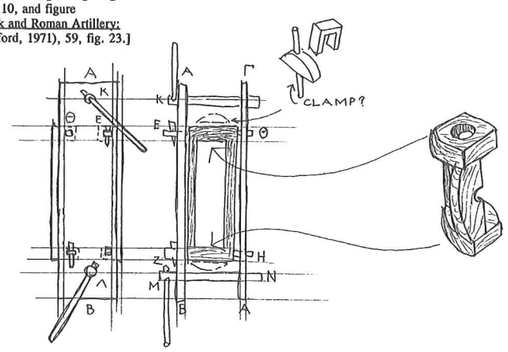
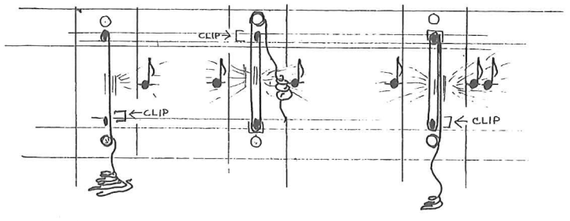


Figure 132. Artillery: The *Ballista* (10.11.1–9).

THE TENSIONING OF WAR MACHINES (10.12.1-2)

stretching frame for a catapult spring
[after Heron, Bel. 107-110, and figure in E.W. Marsden, Greek and Roman Artillery: Technical Treatises (Oxford, 1971), 59, fig. 23.]





hypothetical reconstruction of stretcher for entire headpiece (two springs)

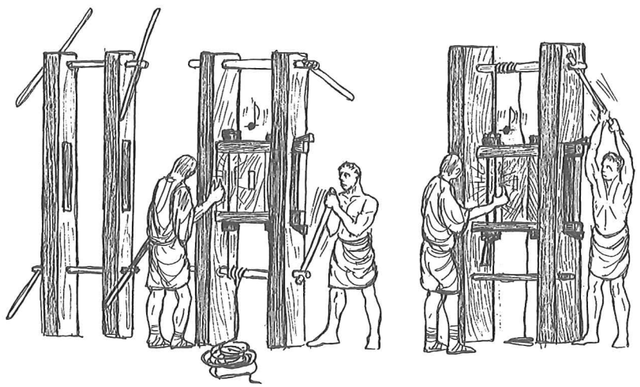
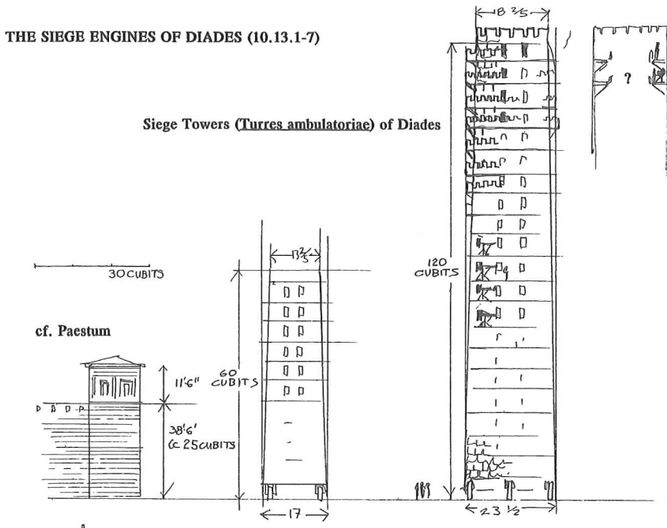


Figure 133. The Tensioning of War Machines (10.12.1–2).

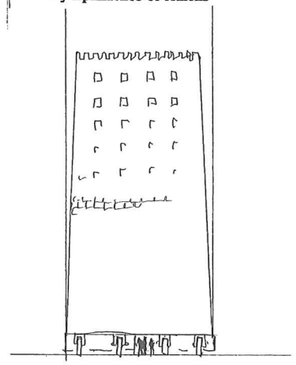
THE SIEGE ENGINES OF DIADES (10.13.1-7)

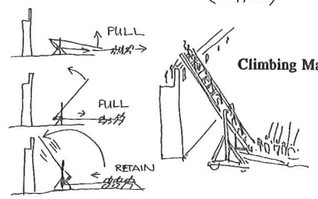
Siege Towers (Turres ambulatoriae) of Diades



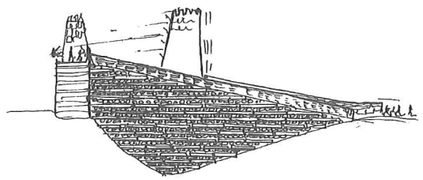
cf. Paestum

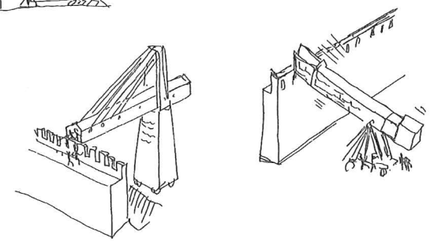
Helepolis of Demetrius Poliorcetes, by Epimachos of Athens



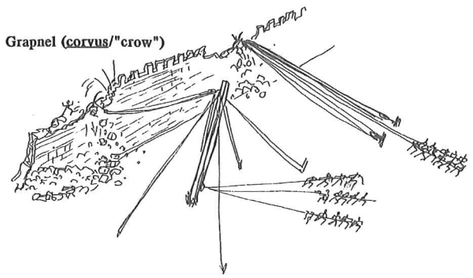


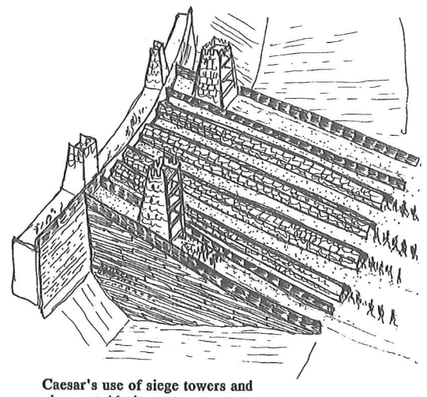
Climbing Machine (ascendens machina)





Grapnel (corvus/"crow")



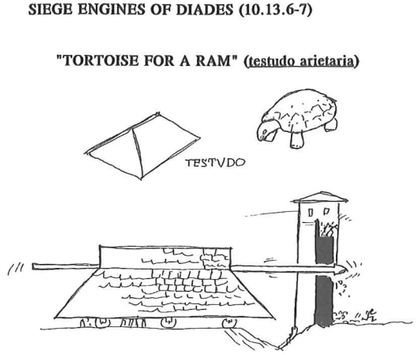


Caesar's use of siege towers and vineae at Alesia

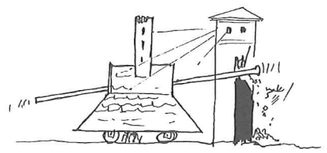
Figure 134. The Siege Engines of Diades (10.13.1–7).

SIEGE ENGINES OF DIADES (10.13.6-7)

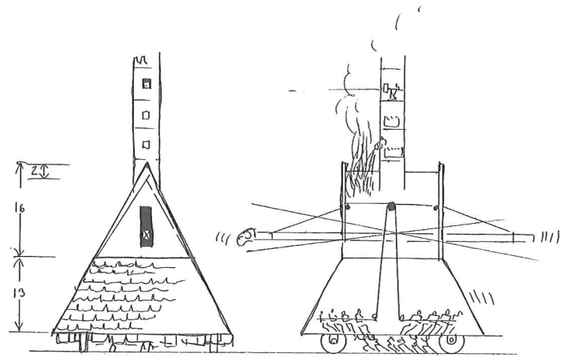
"TORTOISE FOR A RAM" (testudo arietaria)



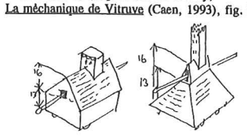
Purpose of the terebra as to punch through the wall at one spot, by hitting repeatedly and precisely.



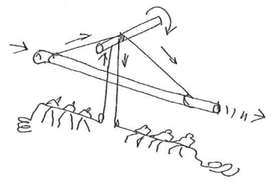
Purpose of a ram was to knock of the top courses of the walls, course by course.

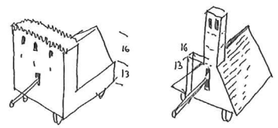


Alternatives (in part after P. Fleury, La méchanique de Vitruve (Caen, 1993), fig. 72).

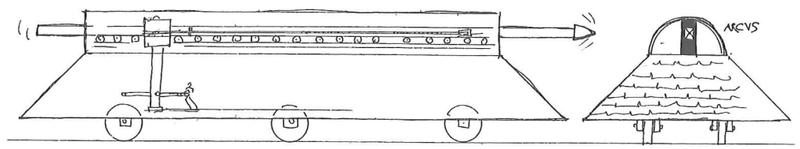


tornus





BORER (gouge, penetrator, punch)(terebra)



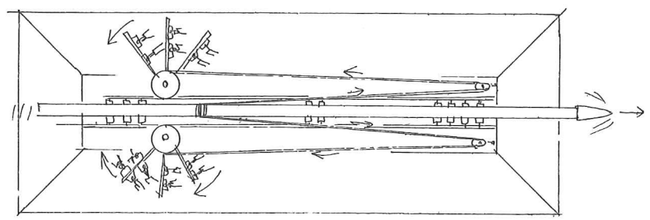
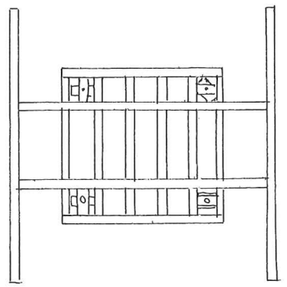
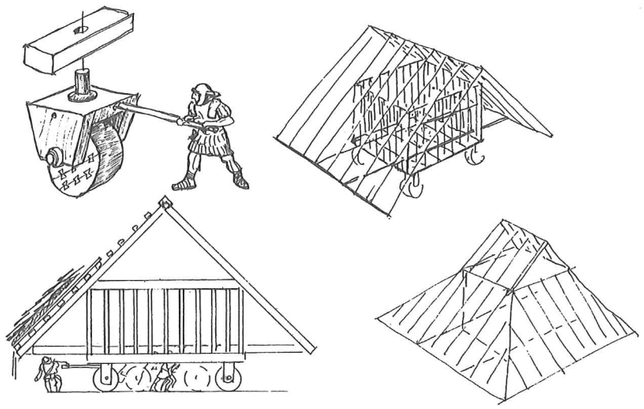


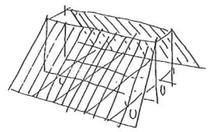
Figure 135. The Siege Engines of Diades (10.13.6–7).

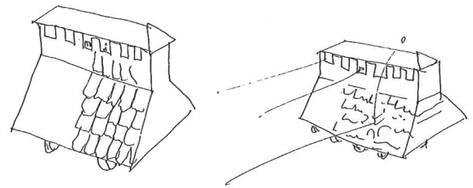
THE TORTOISE FOR FILLING MOATS
(testudo ad congestionem fossarum) (10.14.1-3)





OTHER TYPES...(10.15.1)





DIGGERS (oryges)(10.15.1)

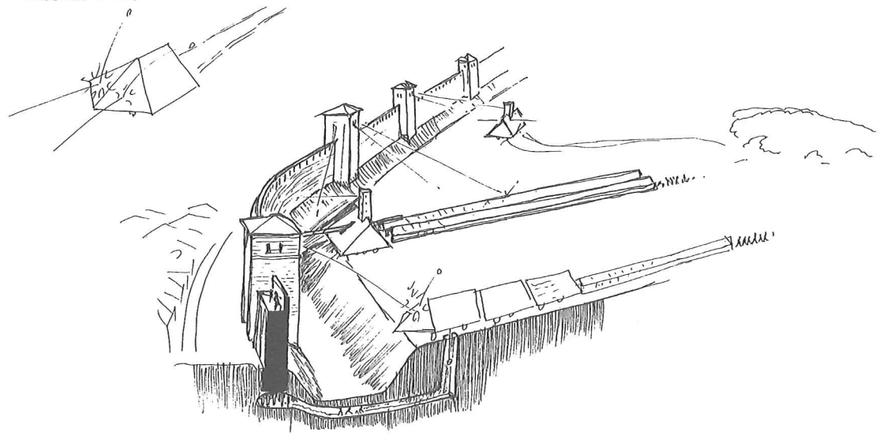


Figure 136. The Tortoise for Filling Moats (10.14.1–3).

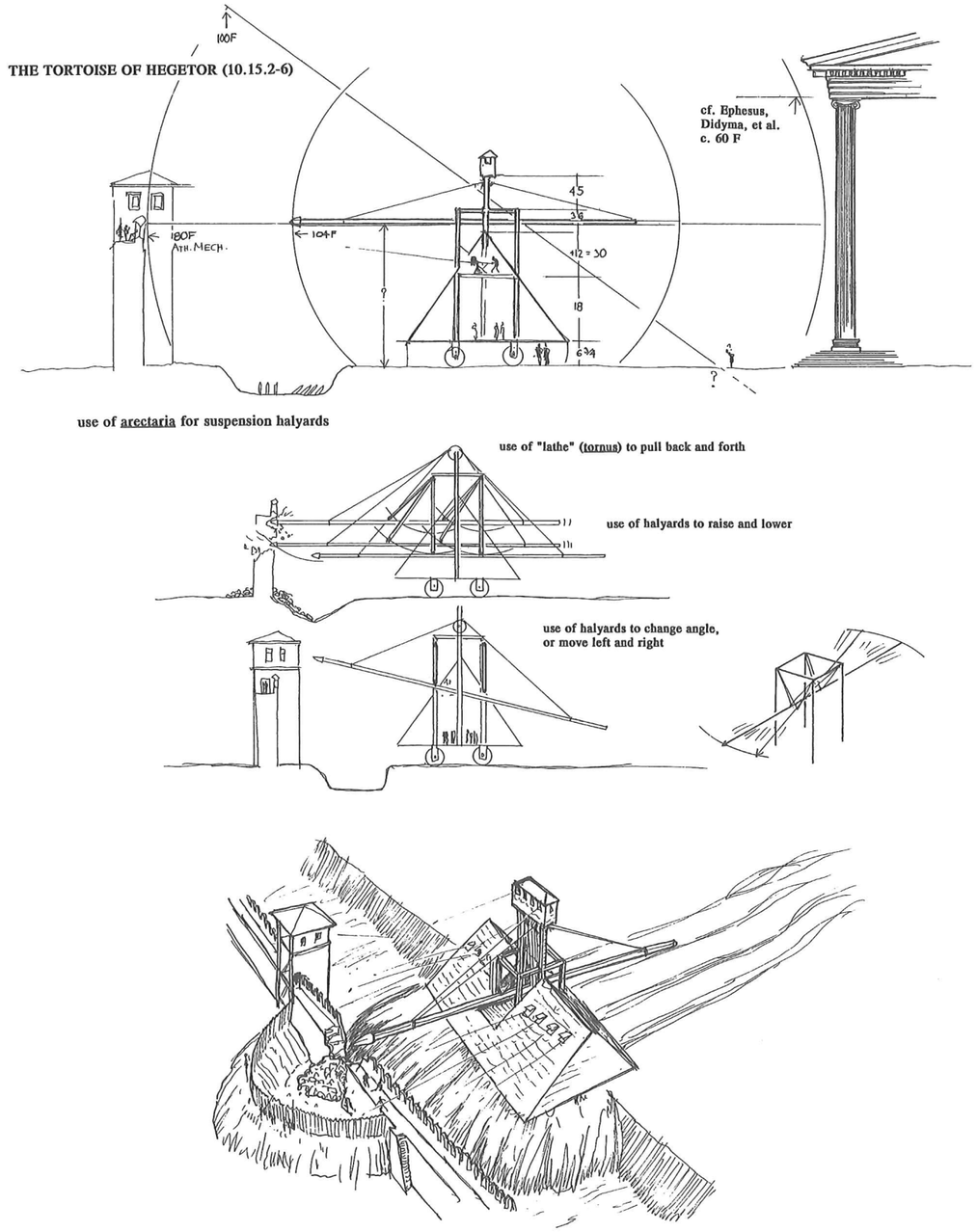


Figure 137. The Tortoise of Hegetor (10.15.2–6).

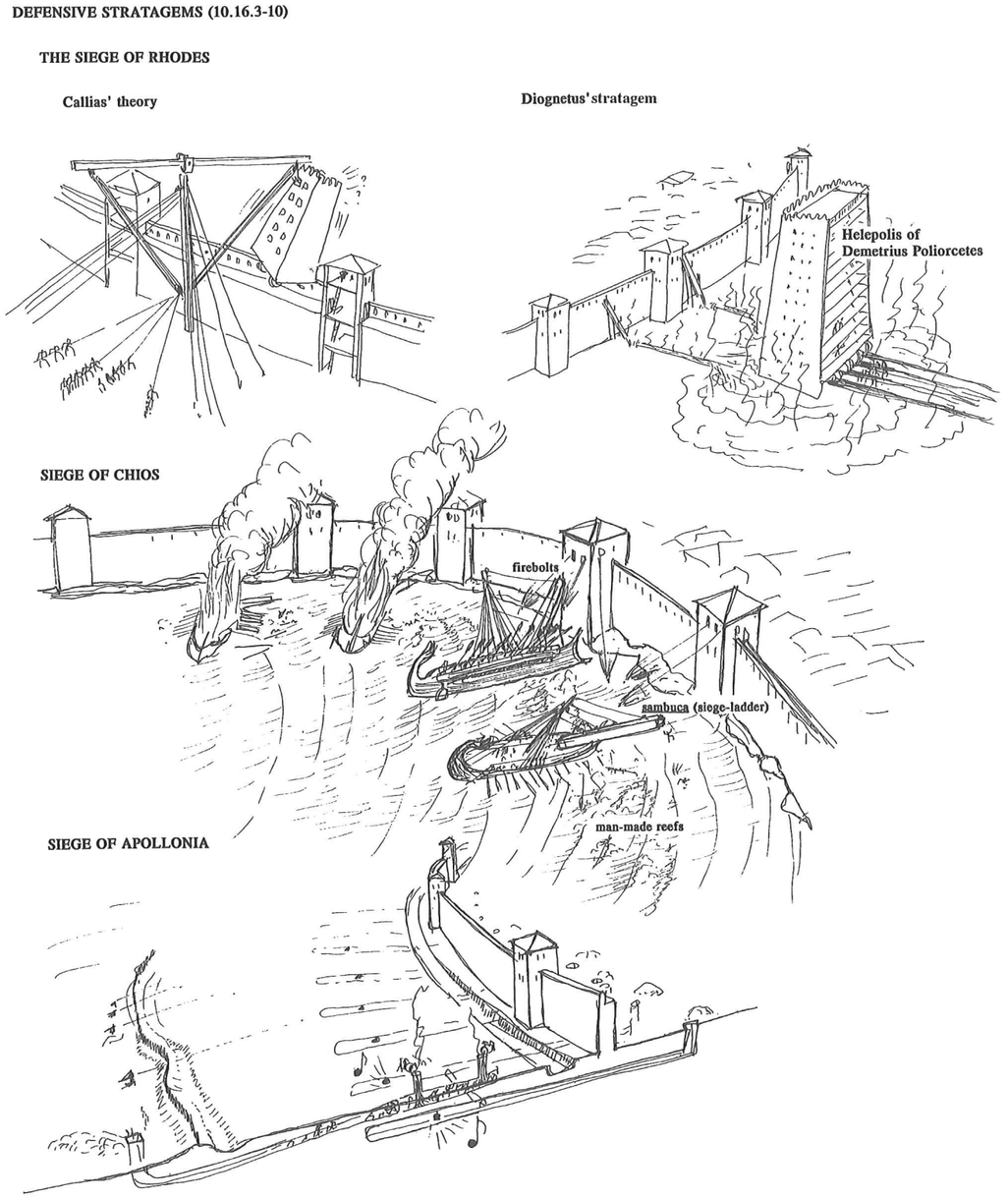


Figure 138. Defensive Stratagems (10.16.3–10).

DEFENSIVE STRATAGEMS: THE SIEGE OF MASSILIA (10.16.11-12)

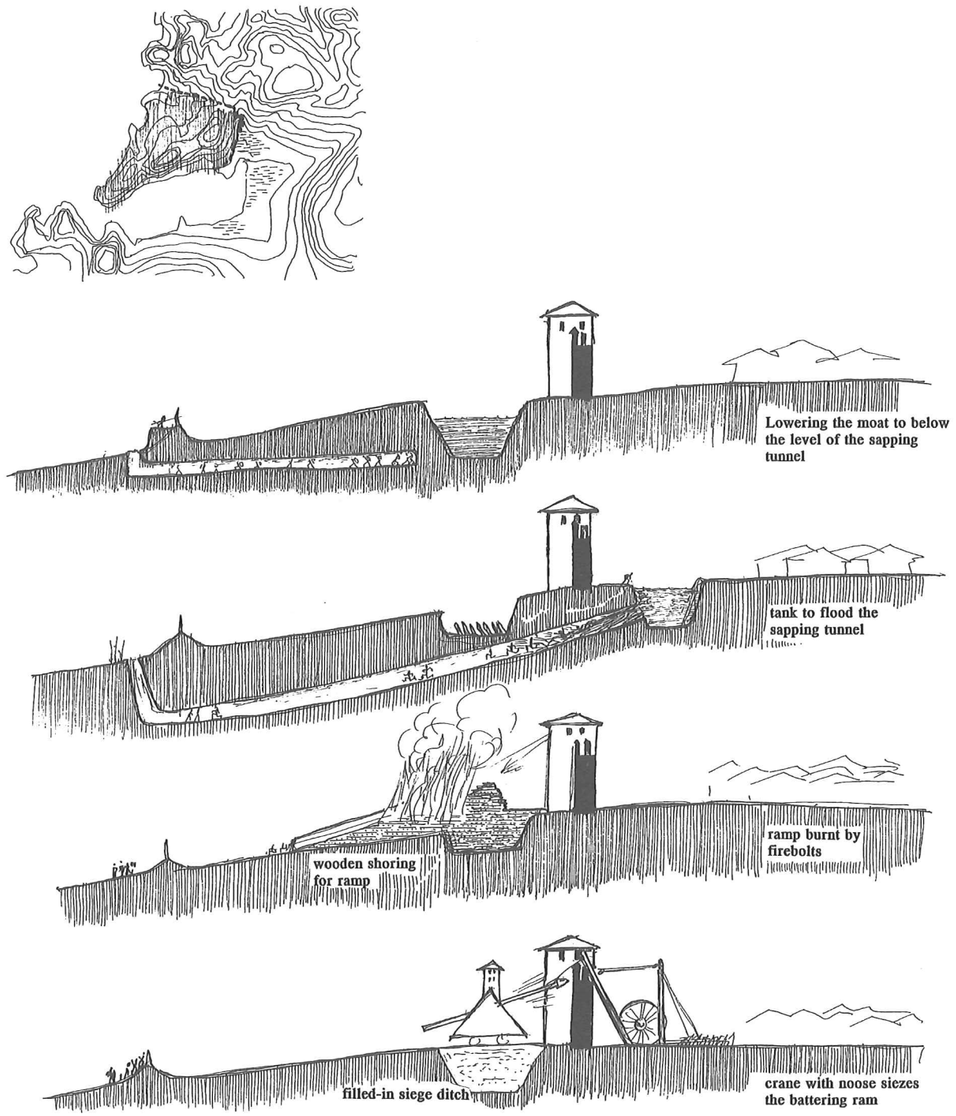


Figure 139. Defensive Stratagems: The Siege of Massilia (10.16.11–12).

Massilia (10.16.11–12) (Figure 139)

This is presumably the siege of Massilia in 49 B.C. The city had been induced by Pompey to make an isolated stand, and the siege, conducted largely by D. Brutus and C. Trebonius in Caesar's absence, was intended to secure Caesar's rear before going on to face Pompey at Pharsalus. Massilia was one of the leading cities in siegecraft and one of those which possessed staffs of trained engineer/architects; others included Alexandria, Byzantium, Rhodes, Syracuse, and Athens. Vitruvius terminates the *Ten Books* with this historical anecdote in order to drive home the point that the ingenuity and "cleverness of architects" (*architectorum sollertia*) triumph over mechanical methods. Oddly, his closing anecdote features a siege in which the Caesarians, and Vitruvius, if he was present, were (temporarily) among the losers. Caesar's account of the siege focuses mainly on the sea battles, although later[27] he does describe the failure of the siege machines and of various stratagems, but makes no mention of problems with the mines and the moat. Caesar was present to accept the capitulation of Massilia before moving on to cross the Rubicon.[28]

27 *Bellum Civile* 2.2.
28 Caesar, *Bellum Civile* 1.34–36; 1.56–58; 2.1–16; 2.22.

INDEX

Page numbers in *italics* refer to illustrations.